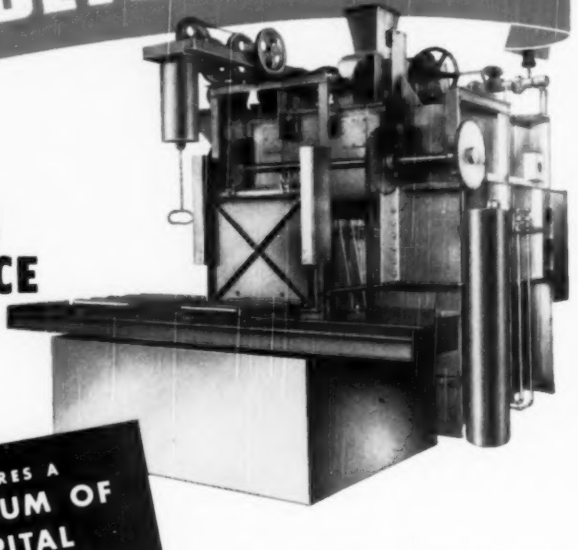
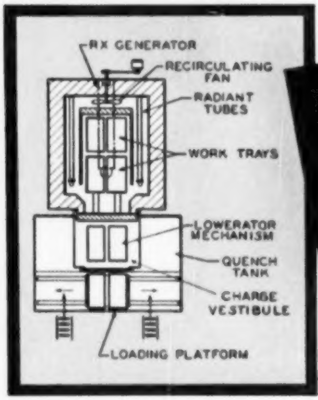
METAL PROGRESS

A ★ *New* AND IMPORTANT DEVELOPMENT



'Surface' HIGH PRODUCTION BATCH-TYPE FURNACE

***WITH BUILT-IN RX ATMOSPHERE GENERATOR**



REQUIRES A MINIMUM OF CAPITAL INVESTMENT PER POUND OF CAPACITY

DESIGNED FOR GREATER ECONOMY OF PRODUCTION

'Surface' researchers and engineers have combined all the time-proven features of furnace design into a unit that meets all the requirements for LOW COST, HIGH PRODUCTION of heat treated pieces.

Investigate its Cost Reducing Possibilities for your plant — Today! There is no obligation.

**Optional*

★ **HIGH-RATE BATCH PRODUCTION . . .** Heats a gross load up to 200 lbs. per hr. per sq. ft. of hearth area, depending upon work and type of loading. Gross charge capacity of furnace up to 2500 lbs.

★ **LOW COST . . .** minimum investment for each pound of capacity. Light case cyaniding can be done for less than one-half cent per pound of work, exclusive of burden and fixed charge.

★ **EXTREME FLEXIBILITY . . .** especially adaptable to *Gas Carburizing, Carbon Restoration (Skin Recovery), Dry (gas) Cyaniding, Homogeneous Carburization, Clean Hardening, and for General Heat Treating.* Recommended for miscellaneous parts such as bolts, screws, fittings, etc., and straight shafts up to 12-13 inches long.

★ **'SURFACE' RADIANT TUBE HEATING . . .** with baffle between the work and the tubes.

★ **FASTER HEATING . . .** fan is used to circulate the heated prepared gas atmosphere around the work to secure a higher rate of heating and improve contact with the load.

★ **BUILT-IN 'SURFACE' ATMOSPHERE GENERATOR . . .** eliminates the need for an external generator, resulting in fuel and floor space economies.

★ **LOADING AND UNLOADING MECHANISM . . .** consists of two alloy screws to move loaded trays in and out of furnace. Furnace holds four trays at a time.

★ **AIR COOLING OF WORK . . .** can be done in the charge vestibule, or—

★ **LIQUID QUENCHING . . .** a lowerator mechanism provides means for oil quenching loaded trays in quench tank built adjacent to front of furnace beneath charging vestibule.

★ **SAVES FLOOR SPACE . . .** overall dimensions approximately 16-feet long (including quench tank) by 9-feet wide by 13-feet high. Occupies only 144 square feet of floor space.

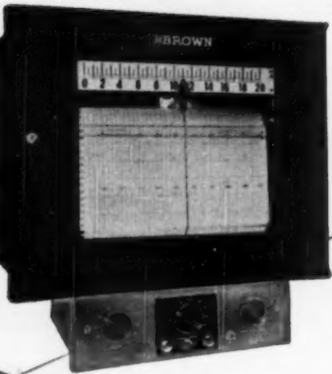
SURFACE COMBUSTION CORPORATION • TOLEDO 1, OHIO

'Surface' INDUSTRIAL FURNACES

DIRECT ROUTE TO

BETTER PRODUCTION

AT LOWER COST



...THE

ElectroniK

CONTROLLER

WITH THE
NEW BROWN
PROPORTIONAL
CONTROL RELAY

HERE'S a combination that's hard to beat . . . the extreme sensitivity of the famous *ElectroniK* Strip-Chart Controller used to its fullest advantage with the amazing versatility of a truly modern proportional relay. Their proper use is a sure way to get the most out of your process.

Check these extra features of this new, compact relay!

- *Unmatched sensitivity and stability.*
- *Positive action.*
- *Manual reset adjustment.*
- *Signal lights to indicate fuel valve operation.*
- *Adjustment of 24% to 206% of the nominal proportional band value of the potentiometer's resistor.*
- *Designed for flush mounting.*
- *Drawer-type construction makes it easily accessible.*

It may also be used with the *ElectroniK* Circular Chart Controller . . . is available for any proportioning control installation.

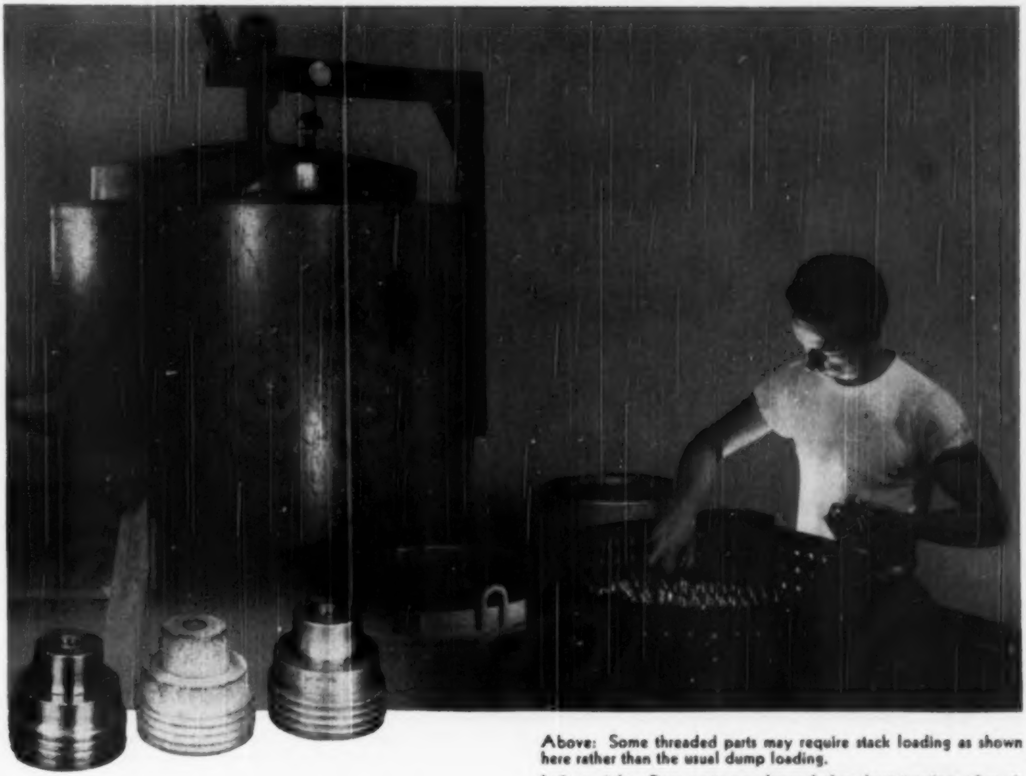
Call in your local Honeywell engineer for a discussion of how this winning combination can add up dollar and cents savings for you . . . he is as near as your phone!

BROWN INSTRUMENTS
WORLD'S LARGEST ORGANIZATION FOR ADVANCED INSTRUMENTATION AND CONTROL

MINNEAPOLIS-HONEYWELL REGULATOR CO.
BROWN INSTRUMENTS DIVISION
4503 Wayne Avenue, Philadelphia 44, Pa.

Offices in 73 principal cities of the United States, Canada and throughout the world

Honeywell — *Advanced Instrumentation* FOR THE METAL PROCESSING INDUSTRY — BROWN



Above: Some threaded parts may require stack loading as shown here rather than the usual dump loading.

Left to right: Brass parts are shown before heat treating, after air atmosphere treatment and after stress relieving in Steam Homo.

Eliminated! four cleaning operations by stress relieving in Steam Homo

Bastian-Blessing Co., of Chicago, has eliminated four cleaning operations by adopting the Steam Homo Method for stress relieving of small brass parts.

The Company makes brass valves, regulators, gas torch nozzles, and other products. Various parts of these products need stress relief, after machining, to prevent what the trade calls "season cracking."

Formerly, this stress relieving was done in an air tempering furnace; brass surfaces came out oxidized as in center picture above. To meet inspection requirements, Bastian-Blessing used successive cleanings in hot potash wash, acid dip, cold water dip and hot water rinse.

All these cleaning operations are now ended by the Steam Homo Method. Parts treated in the protective steam atmosphere come out of the furnace clean. Only appearance change is the slight discoloration shown at right above. This change is so slight that many parts are shipped "as is."

A Thoroughly Practical Method

The Steam Homo Method of stress relieving can be used by any heat-treater. It provides all the familiar Homo advantages of uniform, closely controlled heating, plus steam atmosphere.

A 4-page catalog folder is available from Leeds & Northrup Co., 4927 Stenton Ave., Phila. 44, Penna.

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

LEEDS & NORTHRUP CO.

Jrl.Ad TD2-626(1)

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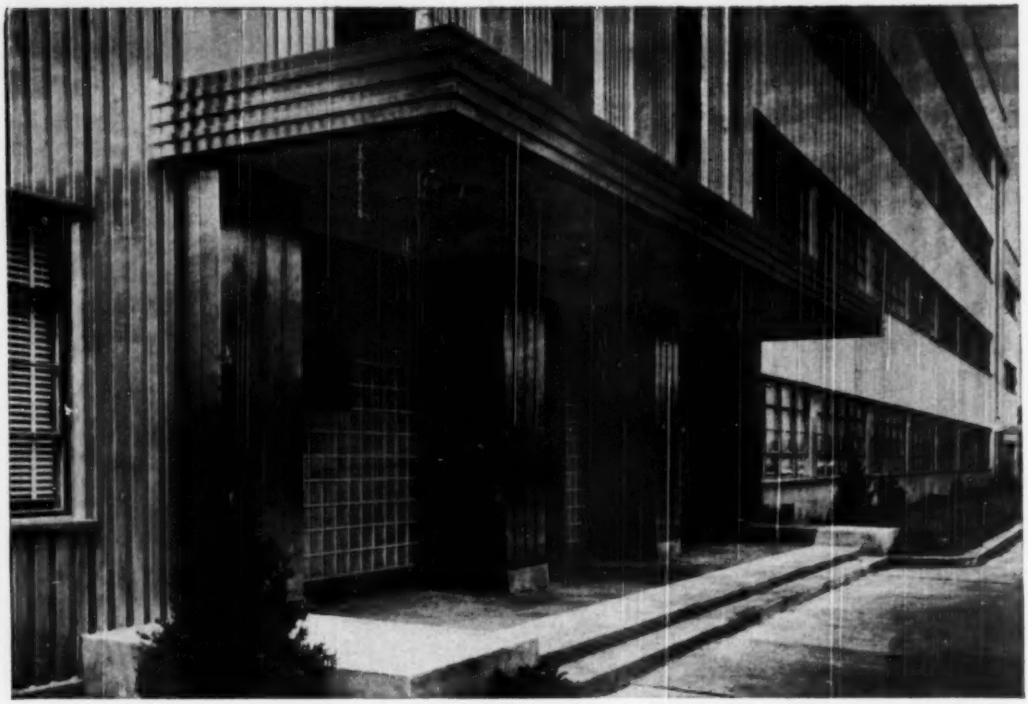

Stone and Webster Engineering Co., Boston—Architects and Builders
Allegheny Metal wall panels fabricated by H. H. Robertson Co., Pittsburgh

strikes the modern stainless note with ALLEGHENY METAL

For certified data on individual grades of Stainless Steel, use

ALLEGHENY LUDLUM BLUE SHEETS

There is a Blue Sheet for each individual grade of Allegheny Metal, giving full information on its physical and chemical properties and characteristics. Let us send you this certified, laboratory-proved data on the stainless grades in which you are interested.

ADDRESS
DEPT. MP-4

The 4-story, 460-foot long office building that fronts GE's new turbine plant in Schenectady is an architectural first. The walls are 3-inch thick insulated stainless steel panels instead of the usual masonry . . . and no departure from old, time-worn methods was ever better justified.

Beside the obvious advantages of lustrous beauty and lifetime resistance to atmospheric corrosion, the use of stainless walls meant increased floor space, speedier construction, lower erection costs, and big savings in maintenance and depreciation costs. Insulating qualities were superior to a 12" plastered masonry wall. Weight was so much less that four stories could be placed on structural steel and foundations designed originally for three floors in masonry. Cold-weather construction problems were eliminated, and working conditions were safer and cleaner due to the virtual elimination of material elevators, scaffolding and forms.

Where can *you* use Allegheny Metal to similar advantage? Let our Technical Staff help you.

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STEEL CORPORATION
Pittsburgh, Pa.

Nation's Leading Producer of Stainless Steels in All Forms

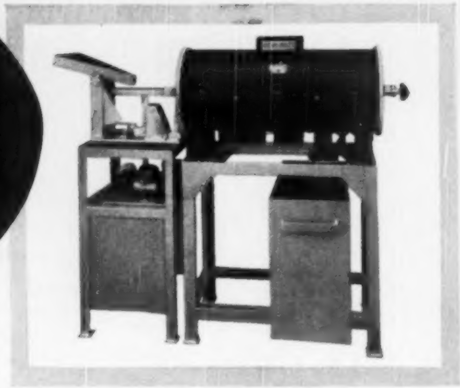
A-L

W&D 2764

ALLEGHENY METAL is stocked by all Joseph T. Ryerson & Son, Inc. warehouses

BRIGHT {CARBURIZING CYANIDING HARDENING

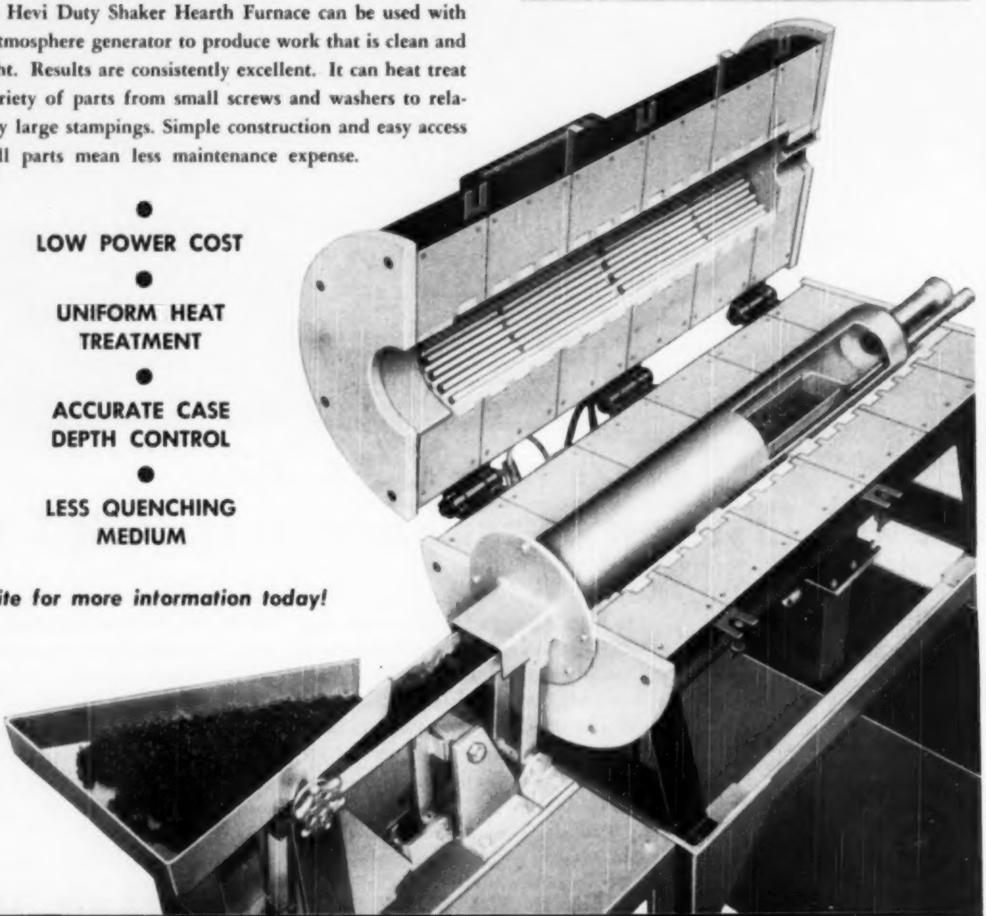
WITH THE NEW HEVI DUTY SHAKER HEARTH FURNACE



This Hevi Duty Shaker Hearth Furnace can be used with an atmosphere generator to produce work that is clean and bright. Results are consistently excellent. It can heat treat a variety of parts from small screws and washers to relatively large stampings. Simple construction and easy access to all parts mean less maintenance expense.

- **LOW POWER COST**
- **UNIFORM HEAT TREATMENT**
- **ACCURATE CASE DEPTH CONTROL**
- **LESS QUENCHING MEDIUM**

Write for more information today!



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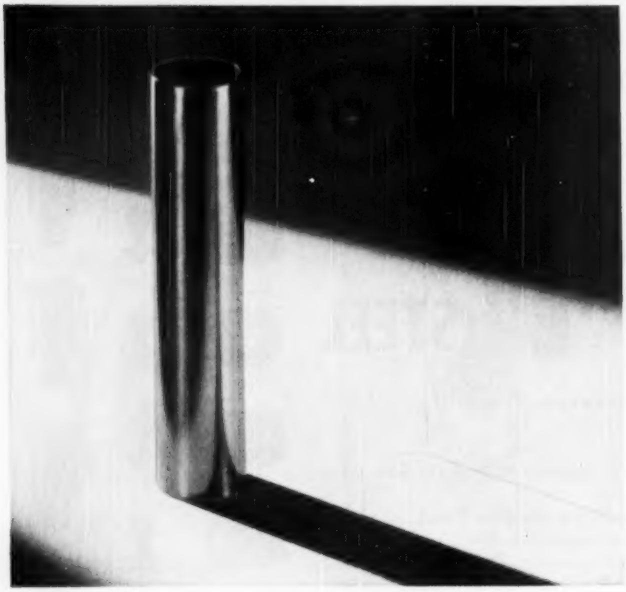
HEAT TREATING FURNACES **HEVI DUTY** ELECTRIC EXCLUSIVELY

DRY TYPE TRANSFORMERS — CONSTANT CURRENT REGULATORS

MILWAUKEE 1, WISCONSIN

Can You See <u>Two</u> Tubes?



● There were actually *two* tubes in this unretouched photograph. One at the right was so fine—less than the diameter of a human hair!—that the screen in the printing plate almost eliminated it. The other is a Superior ⅝" O.D. tube.

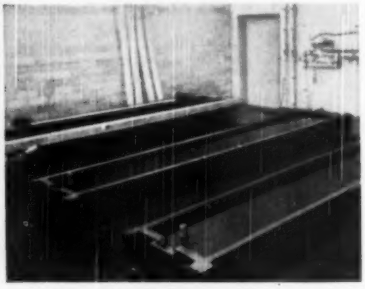
Between these two sizes Superior makes tubing in all practical metals, alloys, forms, finishes, and tolerances.

Between these two sizes Superior is superior for know-how, facilities, metallurgy and technology in tubing.

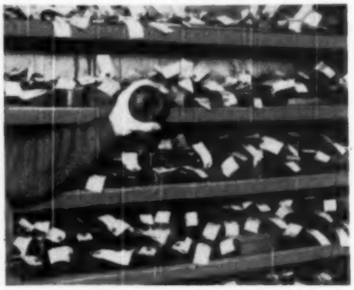
There are 55 Superior Distributors in the U. S. and Canada. You can obtain excellent help, technical assistance, and advice from the one nearest you . . . and can probably obtain just the tubing you need from his adequate warehouse stock.

If you do not know your Superior distributor write directly to us for immediate attention to your tubing problems or tubing needs. Ask for Bulletin 31. Superior Tube Company, 2008 Germantown Ave., Norristown, Pennsylvania.

Superior's Physical Laboratory where tubing samples from every order are tested to make certain that their mechanical characteristics meet the customer's specification. Metallurgical conformity is insured by analysis in other laboratories.



One of the pickling rooms used to clean and pickle tubing. Stainless steels are often used for their appearance value as well as their resistance to corrosion and high temperature. For this reason pickling is more carefully controlled for Stainless steels than for other materials.



Partial view of the dies required for cold drawing and sinking of Superior specialty tubing. Our know-how in die design helps make Superior tubing superior.

Which Is The Better For <u>Your</u> Product . . .

SEAMLESS . . . ? The finest tubes that can be made. In all O.D.'s from 1⅝" O.D. and lower. Excellent for forming, bending, machining, etc. carbon, alloy, stainless, non-ferrous and glass sealing alloys.

Or WELDRAWN*. . . ? Welded and drawn from bright annealed, cold rolled strip. Economical. Available in stainless, non-ferrous and glass sealing alloys, but not in as wide a range of sizes as seamless.

Superior

THE BIG NAME IN SMALL TUBING

All analyses .010" to ⅝" O.D.

Certain analyses (.035" max. wall) Up to 1⅝" O.D.

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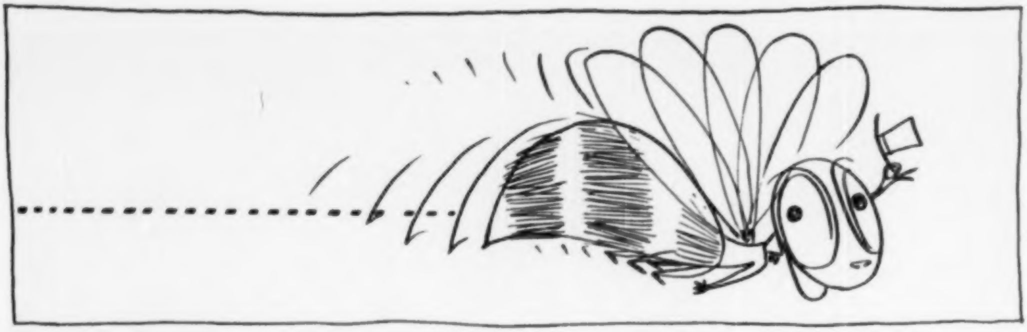
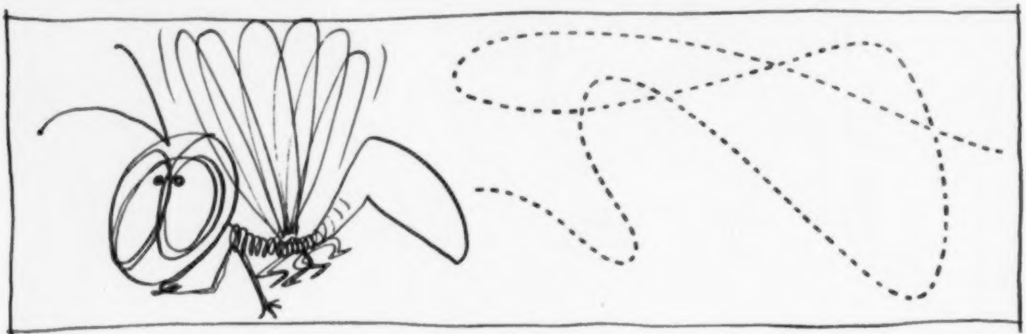
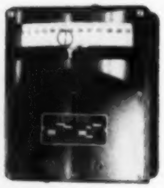




Keep furnace temperature from jitterbugging

BRISTOL Current Input Controller

keeps temperature on a "bee line"



Practically straight-line temperature control in furnaces, ovens, kilns and melting pots is achieved with Bristol's Electronic Pyrometer Controller.

Motors, depressor bars, toggle switches and contacts are completely eliminated from the control circuit. Control is *all* electronic for greater accuracy and elimination of maintenance.

Since the pointer of the pyrometer unit is free to travel throughout its normal range without mechanical engagement, an accurate indication is obtained at all times, along with closer control of the quantity under measurement.

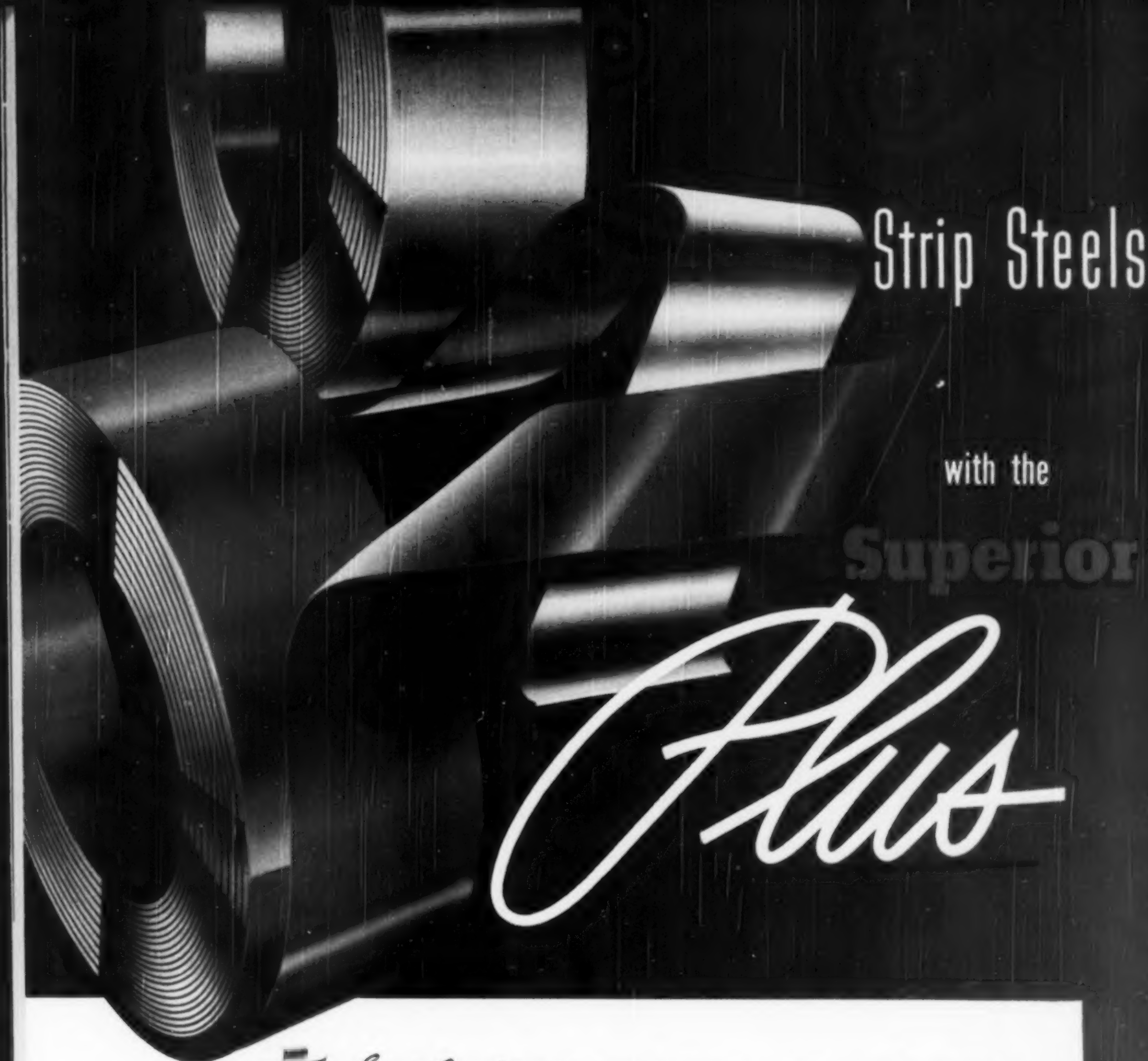
There's no over-shooting the control point on the start-up. No deterioration of furnace heating elements due to wide temperature fluctuations.

Write for Bulletin PB1237. THE BRISTOL COMPANY, 106 Bristol Rd., Waterbury 20, Conn.

BRISTOL

Gives You the Most from Heat

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS


Strip Steels
with the
Superior
Plus

ALL POTS ARE NOT ALIKE!

NO indeed, all pots are not alike. Take for example these ACCOLOY CYANIDE POTS. Every size and shape for each particular job and use. And they differ from all other competitive makes because of their thin wall construction.

Yes, 3/8" wall section in the smaller sizes and 1/2" wall in the larger ones. Made by a casting technique that *controls grain size* throughout the entire pot. No more enlarged grain size under heads or risers.

While a THIN-WALL pot is more difficult to cast, the resultant finer grain size obtained gives longer service life and takes less heating-up time — two vital factors in PRODUCTION ECONOMY.

Before shipping, each pot is thoroughly pressure tested — spot X-rayed — and solution tested to make certain it is free from porosity.

So — for the best in alloy pots, be sure it's ACCOLOY and watch your savings increase.

ALLOY *ENGINEERING* & CASTING COMPANY

ALLOY CASTING CO. (DIVISION)
CHAMPAIGN, ILLINOIS

HEAT RESISTANT CASTINGS
ACCOLOY
STAINLESS STEEL CASTINGS

ENGINEERS AND PRODUCERS OF HEAT AND CORROSION RESISTANT CASTINGS

The Case of the Complete Coverage

The McKay Stainless Electrode line completely covers your requirements for electrodes to weld all types of stainless-steels including the extra low carbon, chrome-nickel steels; the high nickel-chrome, heat-resisting alloys; and the new steels developed for the high-temperature alloys used in super-chargers, heat turbines, jet engines and rockets.

McKay Stainless Electrodes—in Lime, DC Titania and AC-DC coatings—are especially designed to deposit weld-metal similar in chemical analysis and physical properties to the stainless-steels welded with them.

McKay Lime Coated Electrodes are characterized by large, hot arc puddles. The slag, though fluid when molten, freezes quickly and so makes it easy to weld in vertical positions without having the weld-metal fall away from or into the weld.

McKay DC-Titania Coated Electrodes have small, restricted arc puddles and slag that moves quickly away from the arc . . . with the result that there is no slag interference with the arc action and weld beads are smooth and finished. Low spatter loss and easy slag removal make these electrodes ideal where ease of welding and good weld appearance are important.

McKay AC-DC Coated Electrodes are recommended for their arc stability, low spatter loss and ease of operation in vertical, overhead and other positions. They strike and restrike easily with little or no tendency to stick or freeze. The slag produced is easy to control and does not interfere with the arc action. Weld beads are smooth and uniform.

Your inquiries are invited on standard and "special" McKay Stainless Electrodes. Immediate delivery on standard grades.

* * * * * * * * * * * * * * *

McKAY STAINLESS-STEEL ELECTRODES

McKay Welding Engineers will gladly advise you, without obligation on the selection of electrodes and the most efficient welding procedure to obtain best results when welding stainless-steels.

WRITE FOR CONDENSED DATA SHEET ON STAINLESS ELECTRODES

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Down the Line

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Wissco Metal Conveyor Belts are the accepted standard for the heat treatment of metals, glass and ceramic ware and for processing of foods and other products. Whether your processing operation involves extremes in temperature, chemical action or other destructive factors, Wissco Belts are built to take it, for they are made of Monel, Stainless Steel, Bronze and other noncorrosive metals. They offer you these cost-cutting advantages:

Open Weave Construction—*Permitting free air circulation; free drainage.*

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Simplicity of Design—*Easily made endless; readily repaired in case of accidental damage.*

Minimum Operating Costs—*Greatest load carrying capacity per unit weight and low thermal capacity mean fuel economy.*

Send for our illustrated booklet showing types and advantages of numerous conveyor belt constructions. And, if you have any questions on conveyor belts, their use and application ... we will be happy to cooperate in solving your problem.

WISSCO METAL CONVEYOR BELTS ARE BEING USED IN:

Annealing Ovens, Baking Ovens, Brazing Furnaces, Canning, Ceramic Products, Chemical Processing, Decorating Glass, Dehydrating Food, Degreasing, Frozen Foods, Hardening Furnaces, Infra-Red Drying

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A PRODUCT OF WICKWIRE SPENCER STEEL DIVISION OF THE COLORADO FUEL AND IRON CORPORATION

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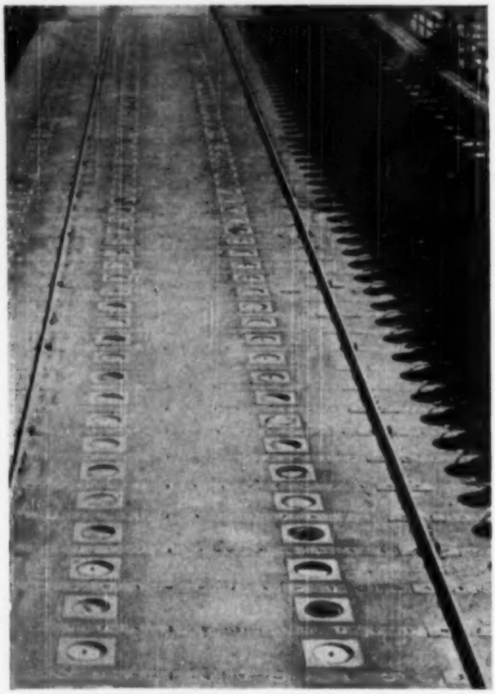
Here's more proof that Lumnite* Concrete is the ADAPTABLE Refractory!



Paving for coke oven battery, Clairton By-product Coke Works, Carnegie-Illinois Steel Corp., Clairton, Pa. Lumnite Refractory Concrete withstands changing temperatures, resists corrosion and its one-piece, monolithic construction remains smooth, outlasting other paving materials.

Base-slab and waste heat flue of heat-resistant concrete made with Lumnite. Withstands heat, and waste gases of burning coke. National Tube Co., Lorain, Ohio.

Coke side of Refractory Concrete door lining in service over ten years when this photo was taken. That's durability! Laclede Gas Light Co., St. Louis, Mo.

Here's Where Lumnite Refractory Concrete Cuts Costs, Saves Time in Coke Plants

Coke plant operators, like many others, are finding more and more time- and money-saving uses for adaptable Lumnite Refractory Concrete. No other refractory material combines Lumnite's refractory properties with such convenience and flexibility of use. Refractory concrete is easily placed in any size, shape or form without skilled workmen. The large number of successful Lumnite installations now in use offers adequate proof of their excellent service records.

WHERE USED: Lumnite Refractory Concrete may be cast in place in coke plants for such uses as: coke oven paving, base pads and flues that last longer, yet cost less to construct and maintain. Refractory Concrete is also useful for many other installations subject to heat, corrosion and severe thermal shock such as backwalls for quenching cars. And, in addition, Lumnite is excellent for precast special shapes—door linings, baffles, blocks for inspection and charging holes, lintels, arches, arch slabs, riser pipe linings and seat blocks, gas gun blocks, caps for top of coke oven, and plugs to fit special openings.

SAVES TIME, CUTS COSTS: Refractory Concrete made with Lumnite calcium-aluminate cement and selected aggregates may be cast in place in exact sizes, shapes and thicknesses desired. Monolithic construction gives maximum durability, reduces outage time for repairs. When repairs are needed, they may be made quickly and easily overnight, because Lumnite reaches service strength in 24 hours or less. Always keep a supply of Lumnite cement on hand. Whether your plant calls for coke ovens or not, you may profit from the properties of time- and cost-saving Lumnite. Write today for further information to Universal Atlas Cement Company (United States Steel Corporation Subsidiary), Chrysler Building, New York 17, New York.

SPECIFY CASTABLE REFRACTORIES MADE WITH LUMNITE

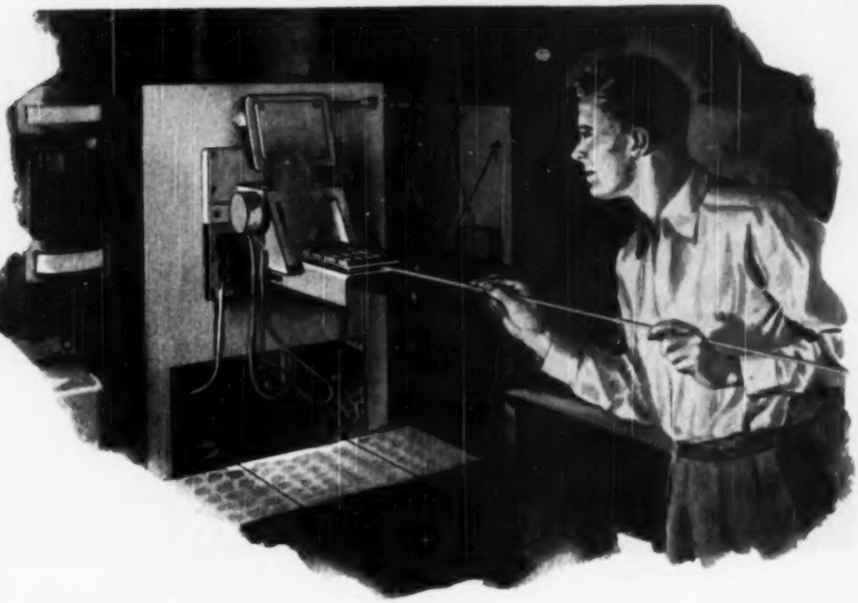
*"*LUMNITE*" *is the registered trade mark of the calcium-aluminate cement manufactured by Universal Atlas Cement Company.*

MP-L-27

LUMNITE® FOR REFRACTORY CONCRETE

A UNIVERSAL ATLAS PRODUCT

"THE THEATRE GUILD ON THE AIR"—*Sponsored by U. S. Steel Subsidiaries—Sunday Evenings—NBC Network*

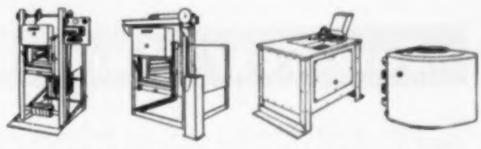


Dependable performance year after year with Hoskins Chromel -equipped Electric Furnaces

There's nothing revolutionary about Hoskins Furnaces, but you'll find them hard to beat when it comes to delivering useful electric heat. And for good reason, too. Because every Hoskins Electric Furnace is equipped with durable CHROMEL heating elements. Long-lasting elements that possess close-to-constant "hot" resistance between 700° and 2000°F., that deliver full-rated power throughout their long and useful life. Dependable heating elements designed to give you uniform distribution of heat with maximum operating efficiency. Important, too, every CHROMEL element in every Hoskins furnace is formed in such a way as to permit quick and easy replacement.

Take the Hoskins FK Brazing Furnace illustrated above, for example. Compactly designed for brazing small tools and parts, it's economical to operate... low in hydrogen and power consumption, quick on recovery. And it's equipped with heavy-duty reverse "U" type heating units made of long-lasting 1" by $\frac{3}{16}$" CHROMEL-A ribbon.

So next time you're in need of good dependable heating equipment, get the facts on Hoskins CHROMEL-equipped electric furnaces. Our Catalog-59R describes the line . . . want a copy?



TYPE FR-206, 207, 208 BOX FURNACE — TYPE FR-251 BOX FURNACE — TYPE OR-104 POT FURNACE — TYPE FR POT FURNACE

HOSKINS MANUFACTURING COMPANY

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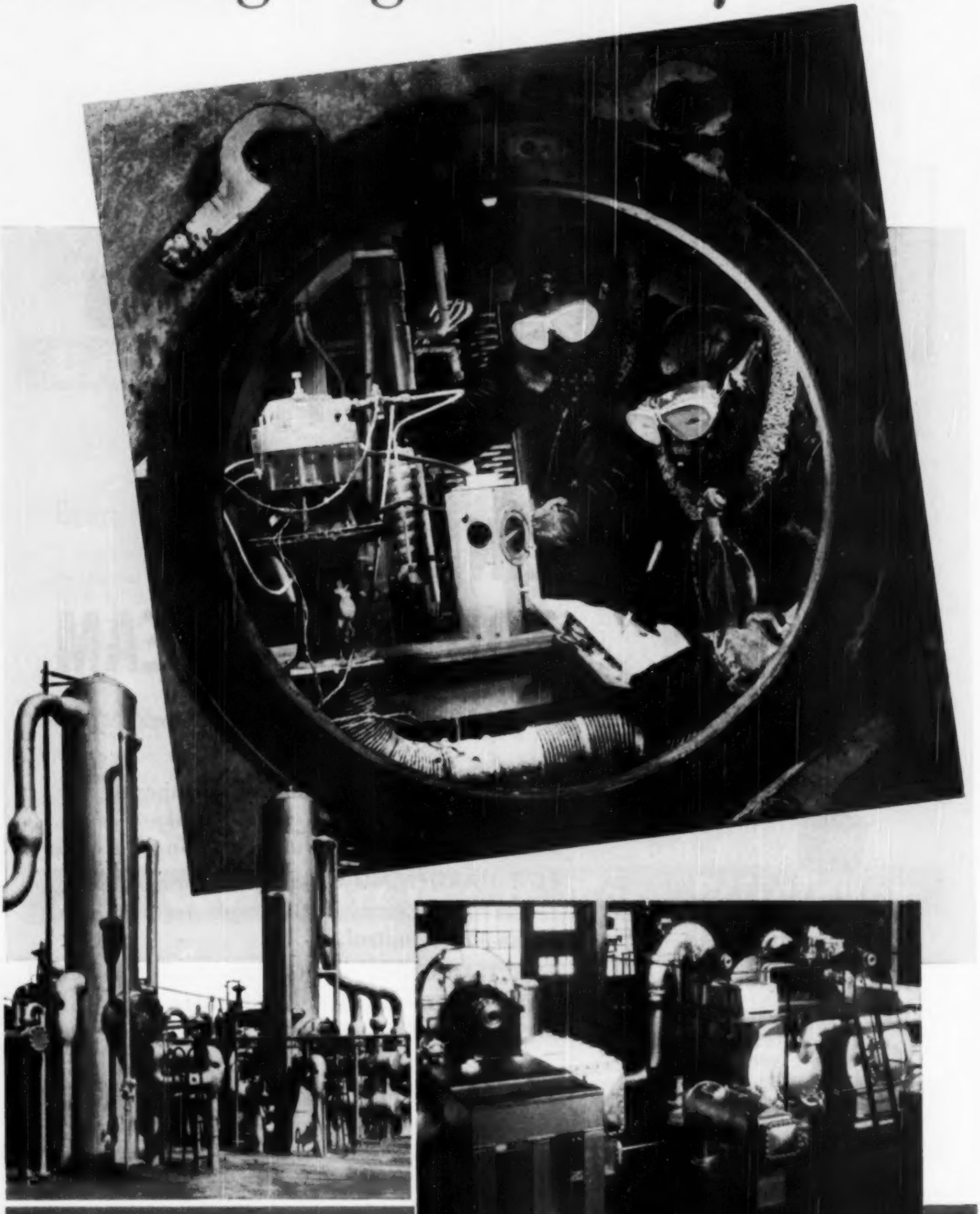
the original nickel-chromium resistance alloy that first made electrical heating practical

Some high-lights on alloy steels



Metal Progress; Page 446

3½ YEARS' SERVICE LIFE

Thermalloy tray and fixture assembly for heat-treating pinions, designed and produced by Electro-Alloys for a leading automotive manufacturer.

with 2 to 1 work/alloy ratio

The Thermalloy* heat-treat tray you see here was designed by Electro-Alloys engineers for a leading automotive manufacturer. It is used for heat-treating pinions in a continuous radiant-tube furnace on a carburizing cycle of 1650°.

Weight of the assembly, considering its size, is not unusually light (23½ lbs.). But the design of the fixture increased the number of pinions it carries from 4 to 9, or the weight load from 20 lbs. to 45 lbs. The result is a large increase in the productive capacity of the furnace.

Yet, heavier loading in no way affected operating life. A number of the original trays *have now been in service over 3½ years.* And the Thermalloy trays have given, on an average, *twice the service life* of competitive trays.

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*Reg. U. S. Pat. Off.

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Inconel's outstanding performance record long ago established it as one of the most durable high-temperature metals available to designers.

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*"New Cleaning Method for Hollow Ware Has Many Advantages" in ELECTRIFIED INDUSTRY, March, 1949.

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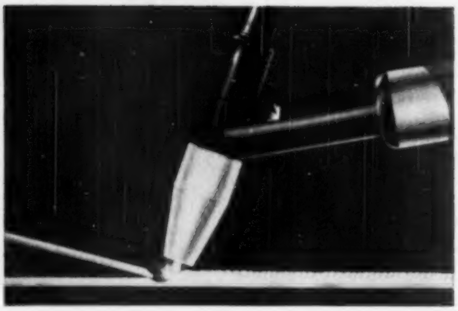
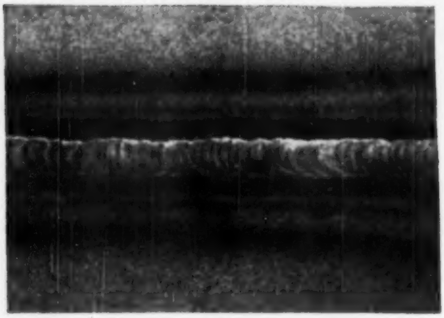


and wipe out one complete operation



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ELECTROMET *Data Sheet*

A Digest of the Production, Properties, and Uses of Steels and Other Metals

Published by Electro Metallurgical Division, Union Carbide and Carbon Corporation, 30 East 42nd Street, New York 17, N. Y. • In Canada: Electro Metallurgical Company of Canada, Limited, Welland, Ontario

How CHROMIUM and TUNGSTEN Increase Strength of High-Temperature Alloys

The aircraft field has served as an important "proving ground" for the high-temperature alloys that have been developed for gas turbines required to operate at elevated temperatures. However, these alloys are now demonstrating their superior properties for other primary power applications, including gas turbines to operate electrical generators for stationary or motive power.

While there are literally dozens of different alloys available for high-temperature use, most of them contain the alloying elements chromium and tungsten for the express purpose of enhancing resistance to scaling and increasing their hardness and strength at elevated temperatures. The amount used is generally determined by the stresses and temperatures expected in service. Other alloying metals may also be added for special purposes — such as columbium, manganese, silicon, and titanium.

Chromium and Tungsten as Strength-Builders

Even small amounts of chromium and tungsten are effective in increasing the strength of high-temperature alloys. An important consideration is, of course, the exposure time—particularly when operating temperatures go above 1200 degrees Fahrenheit. Although the major role of chromium is to prevent scaling, it has been found that chromium, as well as tungsten, also helps the alloys to maintain their strength when they are exposed to high temperatures for long periods of time.

In addition to chromium and tungsten, the combination of other alloying metals present will likewise influence the strength of the alloys. Heat-treatment, too, will influence the properties of these materials. However, in obtaining the higher ranges of strength needed at extremely high temperatures, chromium and tungsten are essential.

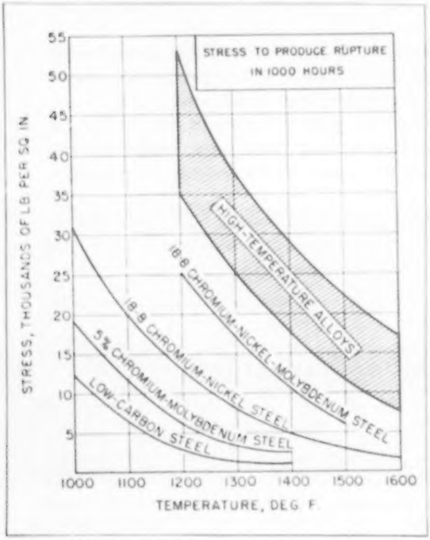


Fig. 1—Here is the average range of strength of various high-temperature alloys compared with other metals.

Where High-Temperature Alloys Are Used

Special high-temperature alloys containing chromium and tungsten are being used for the construction of gas turbines that power railroad locomotives, ships, airplanes, and electric generating plants. Some typical parts made of these alloys are rotors, turbine blades, nozzle vanes, ducts, and housings. These parts are exposed to temperatures of from 1200 to 1500 degrees Fahrenheit.

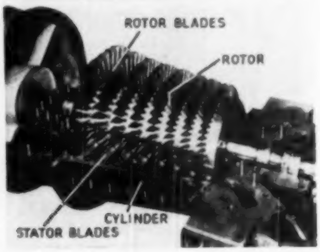
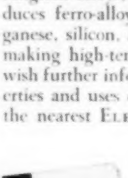


Fig. 2—Rotor and stator blades in this locomotive-type gas turbine are precision-cast of an alloy containing about 24 per cent chromium and 6 per cent tungsten. The rotor body and cylinder housing are forged from an alloy containing about 19 per cent chromium and 1.2 per cent tungsten.

If You Need Technical Help

Those producing high-temperature alloys who wish technical help in the selection of alloying metals will find ELECTROMET's metallurgists glad to cooperate. In addition to chromium and tungsten alloys, ELECTROMET also produces ferro-alloys of columbium, manganese, silicon, and titanium for use in making high-temperature alloys. If you wish further information about the properties and uses of these alloys, write to the nearest ELECTROMET office.



Ask for our new catalog "Electromet Ferro-Alloys and Metals." It describes over 50 metals and alloys produced by ELECTROMET and tells of the unique technical service offered to the metal industries.

Editorial Summary of April Metal Progress

PROVING INTERNAL SOUNDNESS

- Turbine disks and rotors, that spin at high speeds under large centrifugal stress, must for safety's sake be free from even minor internal defects. Ultrasonic tests, verified by sectioning forgings which showed indications, passed 772 of 839 gas turbine disks made of the high alloy 16-25-6. . . . . . . p. 468.

OXYGEN FOR BLAST FURNACES

- Analysis of available information indicates that a low-shaft furnace using 95%+ oxygen blast and producing 1000 tons of iron a day may be able to compete with present-day blast furnaces. . . . . . . p. 467.

QUENCHING GEARS IN OPEN TANK

- Dimensional tolerances on gears are commonly maintained by oil quenching over a plug or in a press, but this is slow and costly in labor. Accurate rear axle pinions can be hardened in an open tank if uniformly supported in a proper fixture and handled smoothly by automatic machinery — that is to say, if they are quenched in a uniform manner. . . . . . . p. 482.

HARDNESS AFTER TEMPERING

- The metallurgist is accustomed to hardenability bands, showing variations in as-quenched hardness among different heats of the same steel. The next step — charting analogous hardness variations (in the 4000 series) *after tempering* — has now been taken by Messrs. Chapman and Jominy. . . . . . . p. 491.

BEWARE RESIDUAL STRESSES

- The design of a simple compressor valve was changed so as to decrease residual stresses caused by quenching. Result: Fatigue life was increased 15 times. . . . . . . p. 480.

SPOTS ON BRASS

- An epidemic of measles (on cartridge cases rather than workmen) broke out in a wartime ammunition factory when pickling vats were replaced by spray booths. The trouble was traced to changes in acid concentration, temperature and aeration. . . . . . . p. 496.

PRECISION HEAT TREATMENTS

- If the modern salt bath had done nothing else but replace the messy cyanide pot with apparatus producing controlled cases, steel treaters would rise up and call it blessed! However, its utility has widened greatly, until it is a preferred method of hardening high speed tools at extreme temperatures. . . . . . . p. 498.

PIG IRON MANUFACTURE

- The modern blast furnace operates at maximum labor efficiency rather than maximum metallurgical efficiency. Present trends are to increase the latter without spending more man-hours per ton. . . . . . . p. 463.

CHEAPER HARDENABILITY TEST

- A new hardenability specimen costs 25% less to machine, and its sensitivity is comparable with that of the "L-bar" widely used for testing shallow hardening carbon steels. . . . . . . p. 474.

WHY DID IT CRACK?

- Stress corrosion is one of the new diseases of metal which have arrived since the discovery of alloys that really resist both stress and corrosion! Research metallurgists are still investigating its symptoms and its cure. In some instances the trouble may be due to atomic hydrogen absorbed by the stainless steel. . . . . . . p. 486.

METAL PROGRESS IN CENTRAL STATIONS

- Large electrical machinery for central stations has developed through three stages, characterized by the metals available — first, the common steels; second, the alloys (steels, copper, silicon-irons); and third, the mammoth forgings and castings of high strength, and high resistance to creep and corrosion. . . . . . . p. 489.

NEXT MONTH • Equipment for Interrupted Quenching . . . New Classification of Metallurgical Literature . . . Transformations in 8630 Steel . . . Martempering Gears in Hot Oil . . . Oxidation of Molybdenum . . . New High-Strength Aluminum Die-Casting Alloy . . . Direct Reduction of Iron Ore

Metal Progress

The Magazine of Metallurgical Engineering

April 1950
Vol. 57, No. 4

Cover Note: The cover is suggestive of equipment for subsurface testing of metal for soundness. The artist is Charles Mitchell

Table of Contents

Published by THE AMERICAN SOCIETY FOR METALS

Improving Blast Furnace Practice*

By P. E. Cavanagh
Assistant Director
Department of Engineering and Metallurgy
Ontario Research Foundation
Toronto, Ontario, Canada

The interesting thesis is advanced that evolution of the iron blast furnace has produced a 1200-ton monster that reduces man-hours of labor to a minimum. Future progress will therefore be toward increasing smelting efficiency without disturbing labor efficiency. Mr. Cavanagh outlines present efforts along this line and estimates their practical limitations.

DURING the last few years the Ontario Research Foundation, on behalf of the Ontario Research Council, has made a detailed study of methods for smelting iron ore in use throughout the world. Two of the objects of our studies were:

1. To discover whether any proven process is capable of producing small quantities of iron at a reasonable cost at locations remote from coal deposits; and

2. To discover whether any process could be recommended if metallurgical coke were no longer available in the required quantities and quality for blast furnaces.

Canada now produces about 3,000,000 tons of steel a year and ranks sixth in the world. We are fortunate that our major markets are situated close to the ore and coal fields of the United States. By far the greatest part of the iron ore smelted in Canada is imported from the United States, as is most of the required coal for making metallurgical coke.

It is certain that at some time in the distant future there will be an end to high-quality coking coal in the United States and its continued export to Canada. While this situation is not likely to arise soon, it has seemed wise to study what our actions would be under such conditions and whether iron could be smelted by some process which would require either much less coke, or coke of a poorer quality and lower strength.

Some of our findings and conclusions are of interest to many other countries besides Canada.

Defining iron ore as a mineral from which iron can be produced at a profit, the most profitable method of smelting it under present conditions is first to treat it in a blast furnace, producing pig iron, which is then refined further in other furnaces into steel. Theoretical objections may be made to this seemingly roundabout method, but economically this two-stage process is the cheapest and most practical in most countries of the world.

The fact that blast furnaces have attained such tremendous size makes possible the mass production of iron and steel, and introduces some factors which make their use very advantageous in a highly industrialized country with supplies of good coking coal — but almost out of the question for countries with very little heavy industry and no high-grade coking coal.

The modern blast furnace, producing over 1000 tons of pig iron per day, is a huge stack about 28 ft. in diameter and 100 ft. in height. As shown in Fig. 1, it is charged with a mixture of iron ore, coke and limestone. On reaching the bottom of the stack the iron ore and limestone become fluid and much

*The first portion (slightly abridged) of a paper entitled "Methods for Reducing the Amount and Quality of Coke Used in Smelting Iron Ore", read before the United Nations Scientific Conference on the Conservation and Utilization of Resources, held in the summer of 1949 at Lake Success, N. Y.

of the weight of the 80-ft. column of charge must be supported on the coke which remains; only the finest coking coals will produce coke of the required strength to withstand this. When it is also realized that the sulphur and ash contents must be low in the coke, it becomes apparent that satisfactory coal for making blast furnace coke for large blast furnaces is not as common an occurrence as good iron ore. Consequently, the location of major iron smelting centers today is determined more by the availability of high-grade coking coal than by the availability of good iron ore.

The iron blast furnace has advanced tremendously in production rate in the last 25 years.

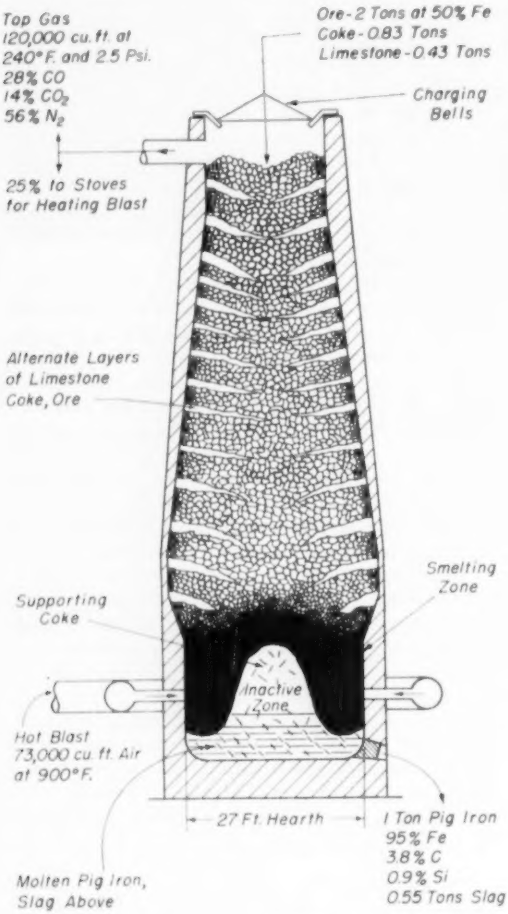


Fig. 1 — Cross-Sectional Diagram of Standard Blast Furnace Stack With 27-Ft. Hearth Capable of Making 1100 Tons of Basic Pig Iron Every 24 Hr.

Size Versus Efficiency — As the size of furnaces increased, the shaft diameter reached a point where the blast of air did not reach to the center of the shaft at the bottom. (From a purely theoretical viewpoint such a large shaft is too big for maximum efficiency, but the smelting of iron is not a theoretical process.)

Large industrial areas have grown up around these steel plants and wage rates have become higher and higher. Since costs for ore, coke, power and other items are fixed unless the technique is radically changed, the man-hours per ton of pig iron became the only major controllable item in pig-iron costs. The labor requirement per ton of pig iron in a modern large blast furnace has been reduced to about 0.75 man-hours, representing about 2% of the cost of a ton of iron. A century ago it was 55%.

The sequence of events has been that in order to get large unit production to satisfy the market and to keep labor costs down, blast furnaces have increased far beyond the size for maximum *smelting* efficiency to a size giving the best possible labor efficiency. Attempts are now being made to increase smelting efficiency without increasing labor costs.

Economizing on Coke

Here the metallurgical engineer is hampered by the fact that the charge is by no means uniform in size or distribution (Fig. 1). The three solid materials present — ore, coke and limestone — are not uniformly mixed. The gas path between the solid pieces of the charge is not uniform, varying across the cross section of the shaft and from top to bottom. For this reason it is often difficult to obtain full utilization of all the gas passing up the shaft. This hot gas, rich in carbon monoxide and hydrogen, must reduce the iron oxide in the ore to iron, and farther up preheat the charge at the top of the furnace. Some of the gas also reacts with carbon and carries it away as oxide, thus resulting in "solution loss" of part of the coke. Better utilization of the gas and its contained heat will reduce the amount of coke necessary to produce this gas and, therefore, the amount of coke consumed per ton of iron produced.

Heated Blast — It is well known that air blast, blown into the blast furnace at the bottom, burns the coke in the smelting zone and produces the required temperature to melt the charge. The utilization of waste heat in the gases drawn off from the top of the furnace and of special stoves to preheat the blast was introduced long years ago and is now standard practice, resulting in major savings in coke.

Blast Volume — At present the volume of air blown into the furnace per minute per unit of area of shaft cross section is being increased tremendously in an attempt to obtain better smelting efficiency and higher production in very large furnaces.

Sized Feed — A great deal of work has been done to determine whether it is practical to select ore in a certain size range and charge it along with coke and limestone (also sized), so that the gas path in the furnace shaft will be more uniform. This simple change in technique sometimes saves coke and increases production; it is profitable where coke costs are high and difficulty is experienced in smelting the ore as received.

Prepared Feed — Many natural ores must be ground very fine when concentrating them to a grade which can be smelted at a profit. Finely ground ore cannot be charged to a blast furnace — for it will simply blow out the top. It is therefore necessary to consolidate such ore by sintering. The ore is moistened, mixed with a small percentage of coke or coal, and fired. The resulting clinker or sinter has a desirable porous, open structure giving ready access to reducing gases.

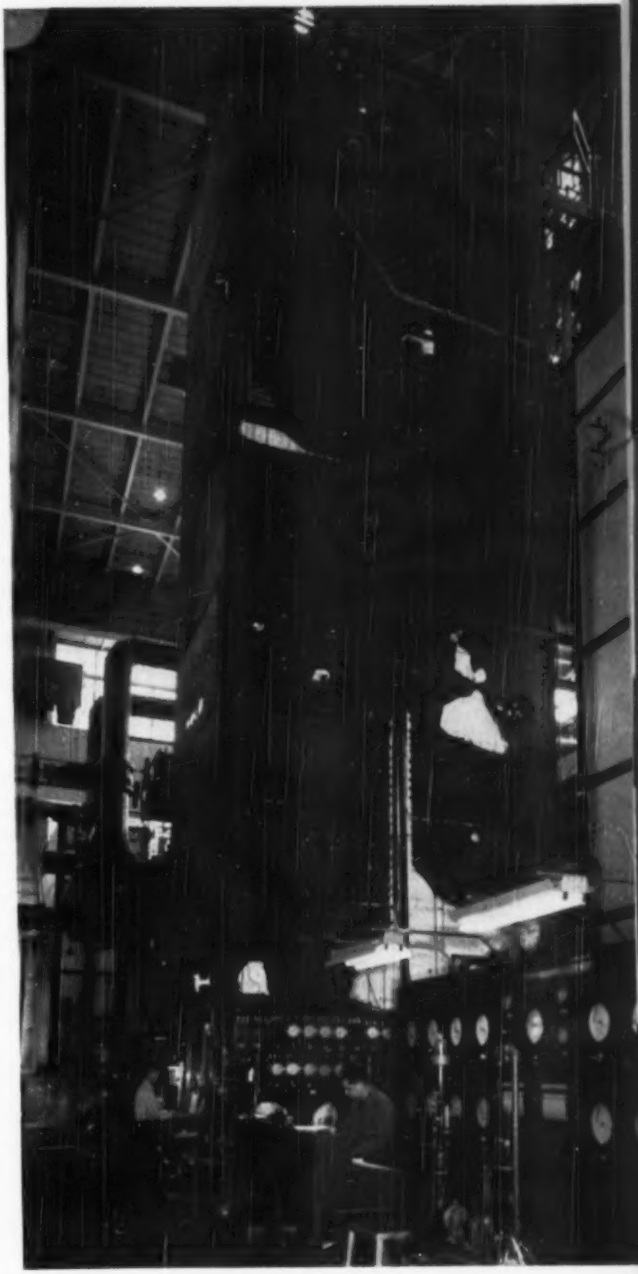
The use of sintered feed has spread rapidly in recent years, even to places where the available ore does not need to be concentrated.

Some ores which cannot be sintered easily can be moistened and formed into small balls or pellets. This pelletizing process may be cheaper than sintering and provides an ideal form of ore feed. It is being extensively investigated at present in the United States, Sweden and Canada.

Blast Pressure — With most iron ores the rate of reduction is governed mainly by the rate at which the reacting gases can reach the ore particles. Only in very dense ores is the diffusion rate of gas into the solid particle a controlling factor in the production rate of pig iron. An obvious way to get more gas in contact with an ore particle in unit time is to raise the gas pressure in the furnace. This scheme has been given considerable attention recently in the United States. Further favorable effects are obtained because the gas stream is slowed down and less dust is carried out. Since the gas leaves the reduction zone at a lower temperature, less coke is consumed by "solution loss" in the upper part of the stack.

Blast Enrichment — Another similar approach to the same problem is to enrich with oxygen the air blown into the furnace. Higher oxygen content gives more rapid combustion of coke at the bottom of the furnace and a "richer" reducing gas rising through the charge — that is, one with a higher potential for converting iron oxide to metallic iron.

The production rate of the furnace will there-



Metallurgical Oxygen Requires Much Power for Compressors and Expensive Equipment Such as the Fractionating Tower Above. It can produce 200 tons of 90% oxygen each 24 hr. (Courtesy Linde Air Products Co.)

fore be increased, but work on standard blast furnaces in Europe during the last 10 years appears to have proved that the consumption of coke will also rise.

The latest plants which produce low-purity oxygen in huge quantities are attaining costs less than $5.00 per ton (24,000 cu.ft.) of oxygen. Even at this price it appears that oxygen can be used only as a "medicine"; that is, when the operation of the furnace becomes irregular or the hearth becomes cold, the oxygen content of the blast can be increased temporarily to correct this condition.

Table I — Coke Conservation by Modifying Present Standard Blast Furnace Practice

Changes in Practice	Iron Production	Operating Conditions			Flue Dust Losses	Coke Consumption
		Blast Volume	Top Pressure	Blast Oxygen Content		
Normal*	100	100	100	100	100	100
Increased blast volume	120	*125*	100	100	150	110
Top pressure	115	100	*160*	100	50	87.5
Blast oxygen	117	100	100	*125*	105	110
Blast volume + top pressure	136	*125*	*160*	100	90	92
Blast volume and oxygen	140	*125*	100	*125*	160	110
Top pressure and oxygen	135	100	*160*	*125*	90	89
Volume and pressure and oxygen	158	*125*	*160*	*125*	100	94

*Normal blast furnace producing about 1000 short tons per day taken as reference = 100, using 55,000 cu.ft. per min. blast volume, preheated air blast at 2.5 psi. top pressure, losing 0.09 tons of flue dust.

Present Operations in North America

In the United States there is no need for drastic modification of the standard blast furnace and smelting techniques, since that nation has been extremely fortunate in having enormous supplies of rich, easily smelted iron ore and good coking coal. Such modifications as are being investigated are summarized in Table I. Table I also endeavors to show the approximate fuel savings which may be expected to result from various methods of improving the efficiency of gas utilization in the blast furnace.

It can be safely assumed that this trend toward increasing efficiency of gas utilization will gain momentum as the grade of available metallurgical coke declines.

The figures in Table I represent the theoretical benefits which can be obtained by the changes in practice shown if the blast furnace design is such that full advantage of the changes can be realized. Blast volume, for instance, cannot be increased indefinitely. For each furnace there is a practical optimum blast volume for most economical operation.

Likewise, the conditions specified in Table I will not necessarily reduce operating costs under present conditions — rather it is intended that the coke savings and production rates should be regarded as ideal figures which may be approached in practice in modern furnaces of this size.

Increasing top pressure appears at present to be the most economical means of decreasing coke consumption, particularly in stoutly built new blast furnaces.

With regard to the supply of suitable metallurgical coke, there is no immediate prospect of serious difficulties. Washing of coal and other measures are helping to maintain coke quality and to produce metallurgical-grade coke from lower quality coals. The grade is, however, slowly becoming lower and the coke consumption per ton of iron is therefore rising slowly in most American iron smelting plants. For example, coke consumption in American blast furnaces was about 4,500,000 tons higher in 1947 than it would have been if coke of the 1941 quality could have been purchased.

Our situation in Canada is different, other than for coke produced at Sydney from mines in eastern Nova Scotia, in that we are at present almost completely dependent on imported coal for making metallurgical coke. Canada now has available large reserves of excellent iron ore. It also has cheap electrical power in some regions. For these reasons there is more incentive for us to develop modifications of present blast furnace technique to reduce coke consumption, or to use alternative processes.

Future Evolution

Anyone examining the information being obtained at present on modifications of present blast furnace technique can see the trend toward

increasing the rate and uniformity of contact between the reducing gas and ore by several methods or combinations of these methods. It appears to be true that the maximum benefits of such a plan as enriching the blast cannot be obtained in a blast furnace of standard design, since the reduction and smelting process is modified considerably by the proposed changes of practice and the present furnace design no longer takes maximum advantage of the conditions existing in different zones of the stack.

This indicates that in the distant future the blast furnace may be modified to quite a different form. The pilot operation of such furnaces which can use low strength and fine solid fuel has already taken place in Switzerland, Germany and Russia. Such a furnace appears to be the only predictable hope for achieving the required large-unit production rates which are absolutely necessary to maintain iron and steel production at the present rates and costs when the supply of high-grade metallurgical coke is seriously reduced.

Low-Shaft Oxygen Furnace

One apparent hope for the future conservation of coke in iron smelting is the low-shaft oxygen furnace described by Pollitzer and Durrer.* As in the low-shaft electric smelting furnace to be described in some detail in a subsequent article, the small amount of gas makes it unnecessary to have a very high shaft, since the work done by it is completed in a very short distance up the furnace. The low shaft naturally reduces the pressure which must be borne by the coke in the charge, and it can therefore be of low strength. Thus the furnace can use a much poorer solid fuel with a large percentage of fines and produce a rich gas fuel. From the point of view of coal conservation, this is a very desirable development. An idealized sketch is shown in Fig. 2.

The modern blast furnace utilizes the best available coking coal and produces a low-grade gas fuel. From the conservation point of view this is a somewhat unsatisfactory use for the highest quality coking coal. A lower grade coal can be used just as satisfactorily in the electric smelting furnace or the low-shaft oxygen furnace.

It is impossible at present to predict the size or characteristics of a large low-shaft oxygen furnace. Low-purity oxygen for this process is produced by compressors driven by electric motors or gas motors. This process, then, requires either cheap electric power or natural gas for compressor motive power. As indicated in the engraving on p. 465, the required plant is rather expensive.

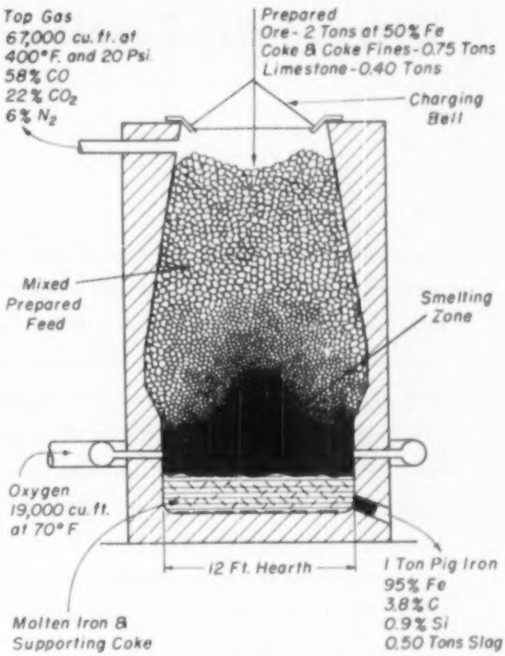


Fig. 2 — Possible Shape of Low-Shaft Furnace Operating on All-Oxygen Blast

The use of pure oxygen (that is, all oxygen, no natural air) combined with high pressure appears to give the best prospect of using the minimum amount of poor coke and keeping the cost of pig iron somewhere near the present level. In order to achieve this result the cost of oxygen must be less than \$5.00 per ton. Such a low cost cannot be attained unless oxygen is produced in quantities of about 1000 tons a day. This means that the oxygen blast furnace cannot compete in production costs with the standard blast furnace until it achieves a size which will produce about 1000 tons of iron per day.

Although such a furnace would not require the equipment for preheating the blast and some of the other standard blast furnace equipment and it would be much smaller, the total investment would be almost the same as for a standard blast furnace and its auxiliaries, since a very large oxygen plant must be provided.

*"Utilization of Oxygen in Smelting Low Grade Ores", by W. Pollitzer, Report P.B. 81385, Office of Technical Services, Department of Commerce, Washington, D. C.

"Production of Iron and Steel with Oxygen Enriched Blast", by R. Durrer, *Journal*, Iron and Steel Institute, V. 156, June 1947, p. 253.

Ultrasonic Testing of Gas Turbine Disks

To correlate the indications derived from the ultrasonic inspection of turbine disks, 22 complete forgings were sectioned and the discontinuities or coarse crystalline regions laid bare. An analysis of inspection reports on 839 such forgings of high alloy (16-25-6 Cr-Ni-Mo) for jet engine disks shows that minor indications found in intermediate stage of forgings are not necessarily a cause for rejection. However, 3.5% of the sound upset blocks developed rejectable defects during the finishing stages of forging. Of the 839 original blocks, 772 finished forgings were accepted, a yield of 92%.

TURBINES are traditionally high-speed machines. Currently, progress in large steam turbines for central power stations is dependent upon the production of huge forgings for the rotors, free from internal flaws. Makers of gas turbines face the same problems. Their units are of small size in comparison; even so, the rotors are closely designed to eliminate weight — not only because the engine is air-borne, but because of the centrifugal forces at high speed and high temperature. The fact that sound wheels of the high alloy required can be made in regular production is demonstrated by a recent survey of 839 forgings for the J33 turbine, based on ultrasonic inspection for internal flaws, recently completed through the cooperative efforts of Allison Division of General Motors Corp., Canton Drop Forging & Mfg. Co. and Timken Roller Bearing Co.'s Steel and Tube Division. The survey provides information pertinent to quality control of turbine disks in production, also to the economic aspects of manufacture and procurement of steel and forgings for other important parts requiring internal soundness.

Turbine disks for Allison jet engines are made of "Timken alloy" (nominally 16-25-6 Cr-Ni-Mo), and they have been inspected by ultrasonic methods for some years. Thus a considerable back-log of experience had been acquired with the method and the interpretation of the indications. As is doubtless well known, the test (an almost simultaneous wartime development in England and the United States) requires an electrical oscillator that sets up bursts of rapid vibrations in a quartz crystal; the crystal periodically acts as a transmitter and induces impulses of short wave length in the metal with which it is in contact; these waves travel through the metal and are reflected back from the far surface or from any internal flaw, and the reflections are picked up by the same quartz crystal (now acting as a receiver) which reconverts them into electrical impulses that are returned to an oscilloscope where they become visible. (Such equipment, both American and British, was first described in *Metal Progress*, September 1945, p. 505-516.)

Such inspection for soundness was first applied only to the partially machined forging, illustrated in Fig. 1. For economic reasons, it seemed judicious also to inspect the forging billets, but it was impossible to penetrate sonically all regions of the billets, due to reflections from coarse crystalline regions contained therein.

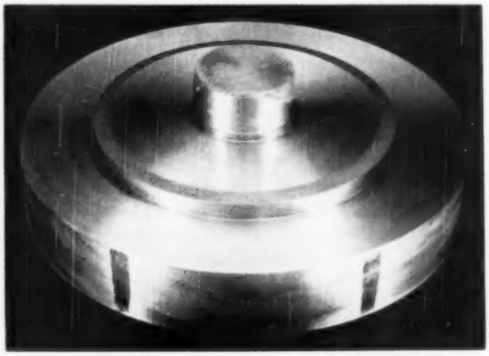
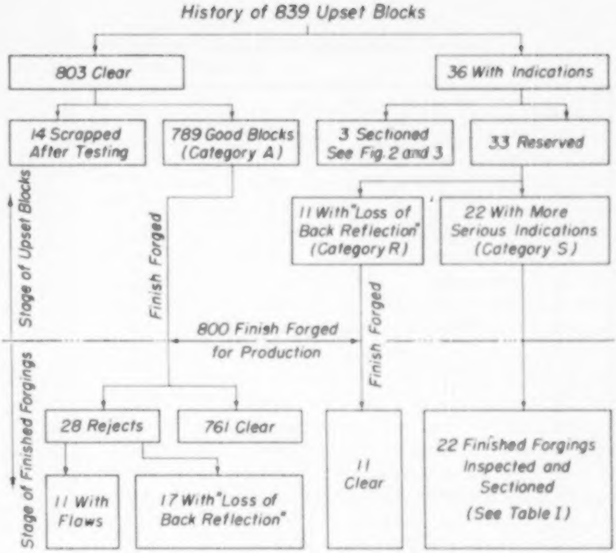


Fig. 1 — Partially Machined J33 Turbine Wheel Forging. Engraving is about one sixth actual size

Inspection after the first upset stage (in which the $8\frac{1}{2}$-in. square billet 18 in. long is upset to about half its length) proved feasible and, thereafter, all such intermediate upset forgings of 16-25-6 alloy were ultrasonically inspected. This was in addition to the final inspection at the stage indicated in Fig. 1.



Inspection of Upset Blocks

The survey now to be reported was based on inspection of 839 partially upset forgings made from 19 different heats. Chemical specifications of the 16-25-6 are 0.12% max. C, 2.00% max. Mn, 0.030% max. P, 0.030% max. S, 1.00% max. Si, 15.00 to 17.50% Cr, 24.00 to 27.00% Ni, 5.50 to 7.00% Mo, 0.10 to 0.20% N.

Inspection was conducted with a Sperry Reflectoscope, Type SRO4B, a contact scanning instrument. A complete search was made over one of the two parallel as-forged faces, using a flat, 1-in. search crystal with a testing frequency of $2\frac{1}{4}$ megacycles. A mixture of glycerine and "aerosol" (a wetting agent) was used to couple the quartz crystal and the metal's surface. The sensitivity of the Reflectoscope was adjusted (Fig. 5) to give about the minimum visible flaw indication from a flat bottomed hole, $\frac{1}{4}$ in. diameter by 1 in. deep, drilled in a machined 8-in. square test block of 16-25-6 alloy when searching on a face opposite the drilled hole.

The inspector reported approximate size and location of internal flaws, and location of search areas that had deficient penetration by the sonic beam (evidenced by reduction in amplitude of the echo from the back face and referred to as "Loss of B. R. or Back Reflection").

As shown in the accompanying diagram of "History", a total of 803 upset blocks showed neither flaw indications nor appreciable loss of back reflection; of these, 14 were used for forge shop tests and scrapped, and 789 (Category A) were finish forged. Two blocks that showed flaw indications and one that contained regions causing more than three-quarters loss of back reflection were sectioned for examination. The remaining 33 of the 839 upset blocks gave flaw indications and areas showing loss of back reflection in varying amounts (or both), and were held for disposition pending a review of the results of the preliminary examination of the three sectioned blocks.

Fig. 2 — Top: Macro-Etched Slice Illustrating Internal Defect in Upset Block No. 23 Located by Ultrasonics. (About one quarter actual size.) Bottom left: Fracture through defect, natural size. Bottom right: Micrograph at 50 dia. illustrating nonmetallic inclusions associated with the defect

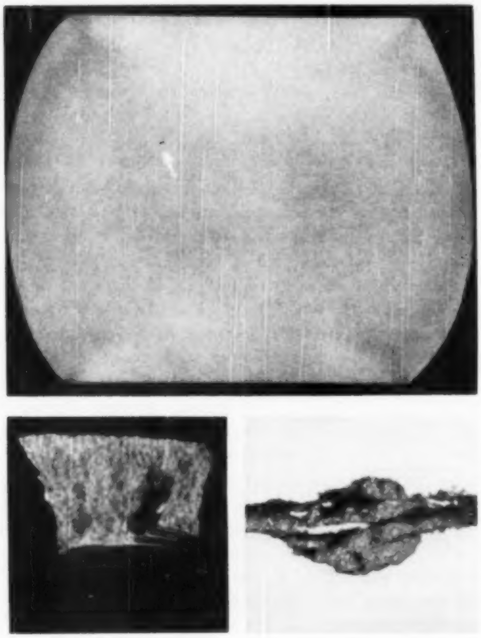


Table I — Summary of Results on Sectioned Forgings With ½-In. Search Crystal

All defects within or near axial region

Code No.	Upset Blocks		Finished Forging		Defect Uncovered
	Indications *(a)*	Loss in B. R.	Indications *(a)*	Loss in B. R.	
1	Medium	—	Large	Total	Large crack
2	Small	—	Medium	½	Small crack, many long pits
3	Medium	—	Large	Total	Large discontinuous crack
4	Small	—	Small	¾	Several tiny discontinuities
5	Small	—	Medium	¾	Fairly large cracked area
6	Small	—	Large	¾	Fairly large cracked area
7	Small	—	Large	⅓	Very small discontinuity
8	Medium	—	Large	¾	Fairly large crack
9	Small	—	Large	¾	Fairly large crack
10 *(b)*	Small	—	Small	½	Small crack *(b)*
11	Small	—	Large	⅓	¼-in. area with inclusions
12	—	¾	None	¾	Traces of coarse crystals
13	—	½ to total	None	¾	None
14 *(c)*	—	Total	None	Total	Pronounced coarse crystals
15	—	Total	None	¾	Traces of coarse crystals
16	Medium *(d)*	—	None	⅓	None
17	—	Total *(d)*	None	½	None
18	—	Total	None	⅓	None
19	Medium	—	None	⅓	None
20	—	¾	None	⅓	None
21	Small	⅔	None	⅓	None
22	—	Total	None	½	None

(a) Indication from ¼-in. flat-bottomed hole in test block is graded as "small" (see Fig. 5). *(b)* See Fig. 4. *(c)* See Fig. 6. *(d)* Near edge of block.

One of the three upset blocks selected for sectioning, Code No. 23, showed large flaw indications about 6 in. from the back face; sectioning and subsequent examinations revealed that it was caused by a rupture associated with a refractory inclusion. This is shown in Fig. 2, p. 469.

The second upset block, Code No. 24, showed a small flaw indication in the center, whose cause could not be ascertained, it possibly being obscured during sectioning. The third, Code No. 25, showed three-quarter loss of back reflection at three locations, which was traced to a coarse crystal structure such as illustrated in Fig. 6, but closer to the search face and opposite face.

The 33 reserved upset blocks were then carefully reinspected. Thirteen of this group that showed flaw indications, together with nine that also contained regions causing a three-quarter or more loss of reflection, were finish forged and reserved for sectioning and check examination, making a total of 22 blocks in Category S. The remaining 11 blocks that showed no flaw indications but did contain regions causing loss of back reflection in varying degrees (Category R) were finish forged for regular production; they were given particular care in the final ultrasonic inspection, and were found to be acceptable.

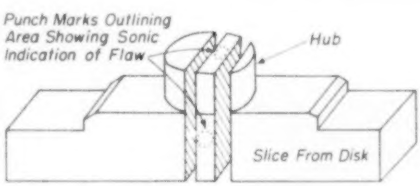


Fig. 3 — Method of Sectioning to Locate Flaw Indicated by Reflectoscope

Inspection of Finished Forgings

The 800 wheels forged from blocks which passed the above test without showing indications were ultrasonically inspected with a flat ½-in. search crystal using a test frequency of 2¼ megacycles, while the 22 wheels in Category S were inspected with both ½-in. and 1-in. flat search crystals using a test frequency of 2¼ megacycles. All searches were conducted in both an axial and a radial direction on all flat faces shown in Fig. 1, using ES-10 grade oil as a couplant between search crystal and metal surface. A 16-25-6 forging known to be free from flaws was used to set the position and amplitude of the first reflection pulse, and the amplitude was then ad-

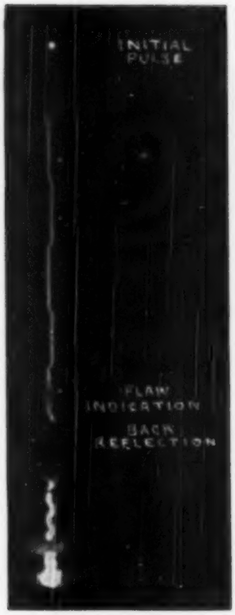


Fig. 5 (at Right) — Reflectogram Showing Bottom of ¼-In. Hole in Test Block

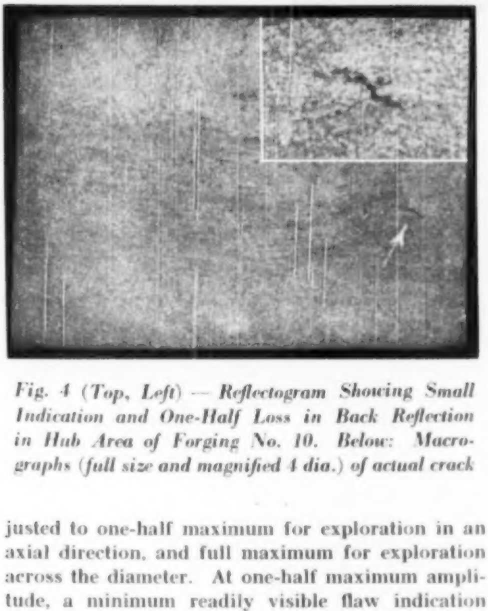


Fig. 4 (Top, Left) — Reflectogram Showing Small Indication and One-Half Loss in Back Reflection in Hub Area of Forging No. 10. Below: Macrographs (full size and magnified 4 dia.) of actual crack

justed to one-half maximum for exploration in an axial direction, and full maximum for exploration across the diameter. At one-half maximum amplitude, a minimum readily visible flaw indication was obtained from the ¼-in. flat bottomed hole in the test block previously described.

Any flaw indication, regardless of amplitude, was considered cause for rejection. A three-quarter or more reduction in amplitude of the back reflection was also considered cause for rejection. (The hub area was also inspected at maximum gain for record purposes only, but not for purposes of rejection.) Reflectogage results on the 22 pieces in Category S, both in the form of upset blocks and as finish forged, are shown in Table I.

A total of 761 finished forgings made from Category A upset blocks that showed neither flaw indications nor appreciable loss of back reflection, plus the 11 blocks in Category B that showed loss of back reflection in varying degrees, passed the final ultrasonic inspection. Twenty-eight forgings made from Category A blocks did not pass this final inspection, 17 because of pronounced loss of back reflection, and 11 because of flaw indications together with pronounced loss of back reflection. These 28 finished forgings were not sectioned.

Ultrasonic inspection of the 22 forgings in Category S selected for sectioning revealed the following information, as contained in Table I: Eleven contained flaws; four contained areas showing three-quarter loss of back reflection (No. 12, 13, 14 and 15); two were satisfactory (processed from blocks No. 16 and 19 showing flaw indications); five were satisfactory (processed from upset blocks No. 17, 18, 20, 21 and 22 showing large loss of back reflection). Sectioning revealed that each of the 11 classified as a "flawed" forging by ultrasonic inspection contained an internal discontinuity in the approximate location indicated; three of the four forgings showing large loss of back reflection were found to have a coarse crystal structure in the location indicated; no irregularities were found in the fourth forging of this group (No. 13).

Sectioning of Wheel Forgings

"Indications" in each suspected wheel forging were within the central portion or hub area. As illustrated in Fig. 3, a slice was cut parallel to the axis to include the entire region beneath the hub. One of the cut faces was then ground, and the slice was again searched over the hub face and ground face and indications punch-marked. Slices were then sectioned by cutting at the extremities of the questionable regions; sometimes excess material above and below was cut away. Thin layers of metal were then removed by machining and grinding until pronounced discontinuities appeared, or until the center of the questionable region was reached. The slabs were examined visually and at low magnification, before and after macro-etching, as each successive layer of metal was removed, and a complete photographic record (Fig. 4) shows the "indication" of a small defect (crack) as it appeared on the oscilloscope screen, as well as macrographs of the actual defect. For

Fig. 6 — Reflectogram Showing Total Loss of Back Reflection in Hub Area of Forging No. 14 (Table I), Together With Full Size Macro Showing Pronounced Coarse Crystals in Indicated Region

purposes of comparison, Fig. 5 is the reflectogram of the indication from the $\frac{1}{4}$-in. flat bottomed hole in the test block. Figure 6 shows a slab from one of the finished forgings that contained no flaw indications, but did contain a region (the penciled circle) that caused over three-quarter loss of back reflection.

Inspection data on the 22 upset blocks and forgings in Category S are summarized in Table I.

Interpretation of Data

The preliminary inspection was able to detect internal defects in the upset blocks, and the indications were generally checked by inspection of the finished forgings.

The upset blocks and corresponding finished forgings did not always allow the same degree of ultrasonic penetration (as evidenced by loss of back reflection). This was found to be associated with a coarse crystal structure, but similar loss of back reflection without an actual flaw indication might also have been caused by a crack lying parallel to the direction of propagation of the sonic beam. Coarse crystal structure also lessens the ability to detect small internal ruptures. Therefore, when an area was encountered in a finished forging that showed a marked reduction in amplitude of the echo from the back face it was considered noninspectable and cause for rejection.

Out of the original group of 839 upset blocks, only 15 (1.8%) showed ultrasonic indications of internal flaws, and 21 (2.5%) contained regions that caused loss of back reflection in varying degrees. Eleven of this latter group* together with 789 in Category A that showed neither flaw indications nor loss of back reflection were finish forged for regular production. Eleven of these 800 finished and rough machined forgings (1.38%) showed ultrasonic indications of flaws, 17 (2.13%) contained regions that caused over three-quarters loss of back reflection, and the other 772 were entirely satisfactory.

As shown in Table I, the flaw indications reappeared in 11 of the 22 forgings from blocks in Category S, and appreciable loss of back reflection in four. Subsequent sectioning confirmed the presence of internal discontinuities in all of the 11, and localized coarse crystals in three of the four forgings showing marked loss of back reflection. The seven wheel forgings (No. 16 to 22 incl.) that showed neither flaw indications nor three-quarters loss of back reflection were all found to be sound and free of any irregularities such as coarse crystals in the structure.

The very design of the finished forging and

*None of the 11 finished wheel forgings (Category B) showed either loss of back reflection or flaw indications.

subsequent rough machining made it impossible to determine definitely what happened to the flaws indicated present in two of the upset blocks in Category S (No. 16 and 19) but they were not present in the corresponding finished pieces. In No. 16 the flaw was located near the edge of the block, and it may have been removed during machining.

Due to the inherent difficulties in sectioning the forgings, the exact size of the discontinuities could not be accurately determined. In general, however, they appeared to correspond to the ultrasonic indications. Some of the defects, when examined microscopically, were associated with refractory type of nonmetallic inclusion segregates, indicating that the discontinuities originated in the steel furnace or pit practice.

Results with the ½-in. and the 1-in. search crystal were quite similar. Better penetration of the sonic beam was obtained with the larger crystal, as evidenced by less loss of back reflection. In a few cases, additional extremely small flaw indications were found, not associated with internal ruptures, discoverable after sectioning. They may have been caused by small scattered nonmetallic inclusions.

Conclusion

The data show that the ultrasonic inspection procedure devised to insure sound internal quality in 16-25-6 jet turbine wheel forgings is entirely practical from a production standpoint. Using the contact scanning method, a forging could be thoroughly inspected in less than 5 min. The results obtained from the 22 forgings that were sectioned demonstrate the reliability of the procedure and show that forgings containing even minute internal discontinuities can readily be segregated from those that are sound throughout.

In addition, the survey provided useful information concerning the economic aspects involved in the procurement of steel and forgings for applications requiring inspection for internal defects. However, it is necessary to section representative samples from each application to provide a commercial basis for the use of ultrasonic inspection.

Nominating Committees

IN ACCORDANCE with the Constitution of the American Society for Metals, President ARTHUR E. FOCKE has selected a nominating committee for the nomination of president (for one year), vice-president (for one year), and two trustees (for two years each). This committee was selected by President FOCKE from the list of candidates submitted by the chapters. The personnel is:

HAROLD L. GEIGER, *Chairman*, International Nickel Co., 333 N. Michigan Ave., Chicago, Ill. (Chicago Chapter).

MORRIS COHEN, Massachusetts Institute of Technology, Cambridge 39, Mass. (Boston Chapter).

COLUMBUS FLOYD, The Babcock & Wilcox Co., Barberton, Ohio (Akron Chapter).

MARS G. FONTANA, Ohio State University, Columbus 10, Ohio (Columbus Chapter).

HENRY HAUSEMAN, JR., La Plant-Choate Mfg. Co., 501 24th St., N.E., Cedar Rapids, Iowa (Cedar Rapids Chapter).

JOSEPH GRAY JACKSON, Wm. Steell Jackson & Son, 112 South 16th St., Philadelphia, Pa. (Philadelphia Chapter).

GEORGE A. NELSON, Shell Development Co., 100 Bush St., San Francisco, Calif. (Golden Gate Chapter).

NEIL M. WATERBURY, Owens-Illinois Glass Co., Alton, Ill. (St. Louis Chapter).

E. C. WRIGHT, University of Alabama, University, Ala. (Birmingham Chapter).

ALSO in accordance with revisions of the constitution adopted in October 1944, a committee for the nomination of secretary (for two years) has also been appointed, consisting of the president of the society as chairman and the six immediate living past presidents. Personnel of this committee is as follows: ARTHUR E. FOCKE, *Chairman;* HAROLD K. WORK, FRANCIS B. FOLEY, A. L. BOEGEHOLD, CHARLES H. HERTY, JR., KENT R. VAN HORN, and MARCUS A. GROSSMANN.

THESE TWO committees will meet during the third full week in the month of May. They will welcome suggestions for candidates in accordance with the Constitution, Article IX, Section 1 (b), which provides that endorsements of a local executive committee shall be confined to members of its local chapter, but individuals of a chapter may suggest to the nominating committee any candidates they would like to have in office. Endorsements may be sent in writing to either chairman or any member of either committee.

A Center Quenched Hardenability Bar for Shallow Hardening Steels

By Earl J. Eckel
Associate Professor of Metallurgical Engineering
University of Illinois, Urbana

TWO widely used hardenability tests for shallow hardening steel are the cone test and the Jominy test using the L-bar. Specimens for both are expensive to machine. The purpose of this investigation was to develop a satisfactory test that would utilize a simpler test bar.

The proposed new test bar shown in Fig. 1 is drilled longitudinally and off-center to give a cylinder of varying wall thickness. The ends of the bars are chamfered around the hole to receive the nozzles of the quenching apparatus. When such a bar is quenched the cooling rate is a maximum in the thinnest section and gradually decreases to a minimum in the thickest section. Hence, by quenching the bar with a stream of water through the hole, then sectioning the bar transversely at its midpoint, and taking hardness measurements on the transverse section in a circle concentric with the periphery of the bar, an indication of the hardenability of the steel is obtained. The appearance of specimens after being surveyed for hardness is shown in Fig. 2. Polishing and etching of the quenched test bars reveal hardening patterns as shown in Fig. 3.

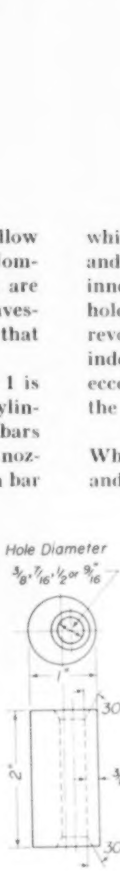


Fig. 1 — New Hardenability Test Piece

Drilling of the eccentric holes is simplified by the fixture shown in Fig. 4, consisting of two eccentric sleeves, one of which can be turned through 360° in the other, and locked at any position by a set screw. The inner sleeve receives a bar 1 in. in diameter and holds it by a set screw. Eccentricity is varied by revolving one sleeve in the other. The sleeves are indexed to facilitate adjustment for a desired eccentricity, and the hole is drilled on a lathe with the fixture held in the lathe chuck.

The quenching apparatus is shown in Fig. 5. When a test bar is to be quenched the nozzles **B** and **C** are moved apart by means of the handle **A**, and the test bar is placed between them. The spring in the upper part of the apparatus holds the nozzles firmly against the test bar. The nozzles are removable and in all tests had the same size holes as the one in the test bar to be quenched. Leaking at the ends of the specimen during a test is prevented by the inspirator effect produced by the rapid flow of water past the contact area.

The necessary control of the water during quenching is made possible by connecting the inlet tube **E** to the outlet pipe of an apparatus used for quenching standard Jominy bars. The various valves of this apparatus are used to vary the velocity of water and to turn the water on and off. The velocity of the water was determined by timing the flow of a given


Fig. 2 — Hardness Marks Concentric With Periphery

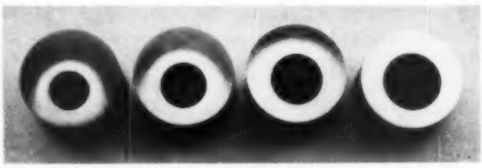


Fig. 3 — Picral Etching Reveals Hardening Patterns

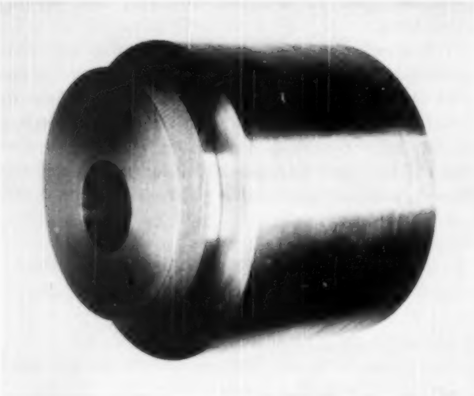


Fig. 4 — Drilling of Off-Center Holes Is Simplified by Eccentric Sleeve Fixture for Lathe Chuck

volume from the outlet pipe D while a test bar was being held in the quenching position.

Procedure — All the tests reported in this investigation were made on 1045 steel, which was received in the form of a 1⅛-in. hot rolled bar. Test bars were machined according to Fig. 1. Four hole sizes were used, ⅜, $\frac{7}{16}$, ½ and $\frac{9}{16}$-in. diameters, and the off-center distance was varied so that a minimum wall thickness of $\frac{3}{16}$ in. was obtained with all the test bars. Two test bars were made of each size. For purposes of comparison two standard and two type-L Jominy hardenability specimens were also made of the same steel. The test bars were packed with wood charcoal and then austenitized by heating for 1½ hr. at 1550° F.

It was believed that greatest uniformity would be obtained in quenching the eccentric bars by using a rather high velocity of water, and so adjustments were made to give a flow of 2000 ml. in 15 sec. with the test bar that had a ⅜-in. hole. For the other hole sizes, the flow was adjusted to give the same average velocity, 6.2 ft. per sec., through the test bar. Under these conditions the times for flow of 2000 ml. of water were 15, 11, 8.4 and 6.6 sec. for the ⅜, $\frac{7}{16}$, ½ and $\frac{9}{16}$-in. holes.

The quenched test bars were sectioned transversely at the midpoint with a cutoff wheel. Then to insure freedom from burning, 0.050 in. was removed with a surface grinder. The surface was further ground on emery papers, using a final paper of 2/0 emery.

It was desirable to take the Rockwell hardness measurements at ⅛ in. from the outer edge of the specimen in order to prevent an edge effect. Since the minimum wall thickness was $\frac{3}{16}$ in., the hardness indentations were centered $\frac{1}{16}$ in. from the edge of the hole at the minimum section. This was not objectionable because of the high hardness at this location.

Because it would be extremely tedious to mark a specimen and take hardness measurements at the desired locations, a fixture was made that enabled the test bar to be centered at a given point on the anvil of a Rockwell hardness tester (Fig. 6). The indentations were centered around the circle by attaching a collar soldered to a large disk marked in degrees (top of Fig. 6). The collar was held in place on the test bar with a set screw and was positioned so that the zero degree line would indicate the placing of the hardness indentation at the minimum section. (Test bars were marked at the minimum section while they were being held in the lathe for drilling.) The hardness indentations were spaced uniformly by making them at 10° intervals, which gave a spacing of about $\frac{1}{16}$ in. At locations where the hardness was low, below about Rockwell C-30, the interval was doubled so that the hardness readings would not be increased as a result of the strain hardening caused by adjacent indentations.

By taking hardness measurements throughout

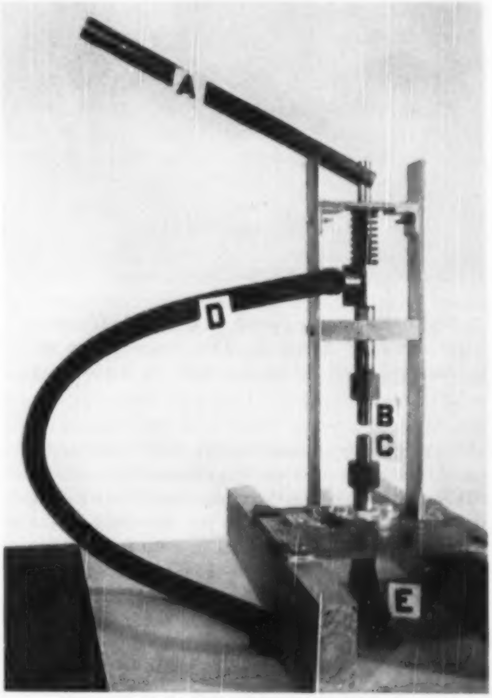


Fig. 5 — Bar Is Quenched Between Nozzles B and C

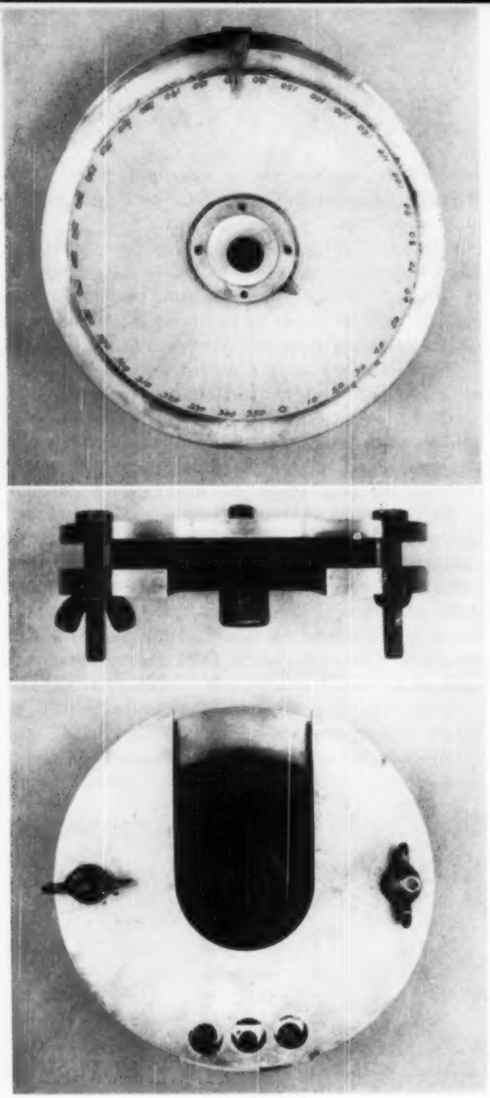


Fig. 6 — Eccentric Specimen Is Held in Position for Hardness Survey by This Attachment to the Standard Anvil for the Rockwell Hardness Tester

360°, duplicate measurements were obtained for each location except the maximum and minimum thicknesses. The hardness readings were averaged for each test bar and then for the duplicate test bars, and the results plotted in Fig. 7.

Discussion of Results — Figure 7 shows that a wide range in cooling rates was obtained by varying the hole size of the test bar from ⅜ to $\frac{9}{16}$ in. None of the center quenched test bars gave a hardness as high as the maximum for the Jominy L-bar. (The minimum section of the eccentric bar — $\frac{3}{16}$ in. as compared with $\frac{3}{32}$ in. for the Jominy L-bar — would lead to a lower cooling rate during quenching.)

It was noted in making the tests that a greater consistency in hardness readings was obtained with the eccentric test bars than with the Jominy L-bars. This seemed to arise from the warpage of the L-bars during quenching. The quenched end of the L-bar expanded during quenching and therefore it was impossible to grind opposite sides

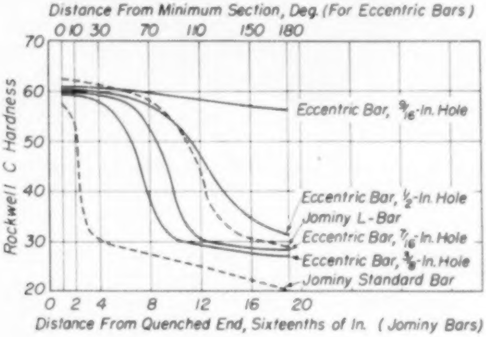


Fig. 7 — The Center Quenched Bar Gives Data Similar to the Jominy L-Bar Hardenability Curve

of the test bar to a definite depth the entire length of the bar. The design of the L-bar is such that the hardness readings will vary with the depth at which the measurements are taken. On the other hand, both the center quenched test bar and the standard Jominy bar are relatively insensitive to slight differences in the depth of grinding.

Conclusions — Experimental work with the center quenched hardenability bar leads to the following conclusions:

1. With routine testing, the center quenched bar gives hardenability data similar to those furnished by the Jominy L-bar but at a cost estimated to be 25% lower.

2. Merely by changing the size and off-center distance of the hole in the eccentric test bar the cooling-rate gradient obtained in the test may be varied to suit the hardenability of the steel being examined.

3. The hardness readings are taken at a constant level below the surface and therefore represent constant chemical composition, providing the test bar is co-axial with the bar or billet from which it came.

4. The hardness measurements are made at a depth of $\frac{1}{16}$ in. or more below the surface and therefore a careful control of the heat treating atmosphere is unnecessary.

Critical Points

By The Editors

Midwest Research Institute

YOU HAVE HEARD of public spirited men (before the days of the high income tax) endowing an art museum to raise the cultural tone of their community, but did you ever hear of them establishing a research institute to increase its reputation as an engineering center? Yet that is just what was done by business men in Kansas City. The idea originated early in the 1940's, when delegations to Washington, seeking wartime industries, were repeatedly brushed off because the bureaucrats thought of cattle, or wheat, or wholesale trade — anything but manufacturing — when they thought of Kansas City. In a campaign led by J. C. Nichols and R. L. Mehornay (whose principal interest, real estate and furniture, respectively, would prosper with the establishment of a better balanced regional economy) the Midwest Research Institute received contributions from over 500 individuals and companies. After a broad study of similar enterprises throughout the United States and Canada, activities got under way in 1945, housed in a building originally intended for studying the bakery problems of a local corporation. Activities are now grouped under four branches: chemistry, physics, engineering and agricultural processes; some 60 technical personnel are employed together with 50 clerical, shop and maintenance staff. Investigations of a metallurgical nature include such things as the improvement of diesel cranks, methods for casting printing plates for rotary presses, and several other fabrication techniques. Undoubtedly the principal aims of the Kansas City founders are being achieved. Better, the influence of the Institute is spreading; only two thirds of the current studies originate in the near-by region; one third have come from far afield — some as distant as New England.

Big forgings for big generators

PROBABLY the nonexpert thinks of a large electrical motor or generator as an assembly of copper conductors, insulation and cooling devices, but C. M. Laffoon, Westinghouse's top generator engineer, mentioned rotors and materials first in the "Mid-Century Review and Forecast Forum" recently held by his firm in East Pittsburgh. Really large equipments (for their day) were limited by available materials and design; development therefore has occurred in three stages. In the first, prior to 1920, speeds were 1200 r.p.m., and the machinery operated below the first critical or resonant speed of the rotating assembly. Then, from 1920 to about 1925, better balanced rotors were safely operated at 1800 r.p.m., between the first and second resonant speeds, even though construction was still of multiple plates or forged disks stacked together and clamped to shaft-ends by heavy through-bolts. Attention was turned in 1925 to large forgings of nickel-chromium, molybdenum or vanadium steel of high elastic limit, and maximum speeds were doubled to 3600 r.p.m. These same developments were utilized in the steam turbine department; one-piece forgings for big rotors were first a manufacturing convenience, now they are an essential. Mr. Laffoon hazarded the guess that steels with 100,000 psi. yield strength would be about the ceiling for future developments. For the present, the steel's cleanliness rather than the test-bar strength is the limiting factor; supersonic inspection methods reveal a disquieting number of stress raisers inside 85-ton forgings from 150-ton ingots, and metal trepanned from such locations has very little ductility (elongation in tensile test).

Such high speeds on rotors — as well as thermal expansions and contractions — overstressed the soft copper conductors and they stretched enough to loosen in their slots. This was corrected by substitution of high-conductivity copper-silver alloy, with a lower creep rate and a much higher true elastic limit. Parallel with these developments were improvements in silicon-irons for stator cores. The story of their magnetic characteristics has been often told; one might infer that present worries concern steel mill and punch-shop operations, flatness, and prevention of burred edges.

IN THAT SAME FORUM, Westinghouse Vice-President D. W. R. Morgan discussed the steam turbine for central stations. He again stressed the problem of metallic materials, separating turbine history into the four ages of cast iron, cast

steel (1910 to 1935), alloy steel and superalloy (since 1945). Blades are the clearest example of this evolution. Bronze blades were earliest used; their peripheral speed was about 400 ft. per sec., steam temperatures about 350° F. at 150 psi. pressure. In the early 1920's the low-carbon, 12% chromium steel blades were introduced, operating temperatures have crept up to 1050° F., pressures to 2000 psi. and speeds at tips are supersonic: 1380 ft. per sec. One gathers that the limitations reside not in the blades but more in the casings, where cast 18-8 stainless is now utilized for the first and hottest stage.

Metals to work at high temperatures

Future improvements in thermal efficiency and other items of economy such as weight and volume reside not so much in increased speeds (Mr. Morgan said the present 3600 r.p.m. is maximum for a dipole generator) as in increase of steam temperatures and pressure. With the metals now used in rotors, blades and casings, steam temperatures can be increased, in his opinion, 50 to 1100° F. and pressures 400 to 2400 psi. Progress beyond that awaits some fundamental metallurgical advances. The possible ultimate would be 3200 psi., the "critical" pressure where water changes to steam with no change in volume; under such conditions a temperature of 1200° F. would be suitable, and an 8% gain in thermal efficiency over the present best turbine could be achieved.

Gas turbines for industry

SUCH metallurgical improvements may come about through the perfection of the gas turbine, a device that Westinghouse engineers have been studying since 1930. In this the materials problem is paramount. Nevertheless the solution will bring rich rewards in enormous increases in fuel economy over conventional power plants. The success of the jet engine in boosting the speed of military aircraft obscures the far less spectacular developments for industry: 2000-hp. gas turbines are now driving pumps on oil pipe lines, and similar units are being tested in locomotives. Their future, in industry as well as in commercial air transport, will depend on cost, dependability and durability.

It is well known that the critical locations in gas turbines are at disks and their attached blades; in both of them high temperature and centrifugal stress require metals with low creep rates — or, better, high stress-rupture characteristics. The Editor discussed his favorite thesis with his old friend, Howard Scott (long heading the metallurgical research at Westinghouse Research Laboratories), expounding the proposition that the thing to discover is an alloy that age hardens just as fast as it creeps. Whether this is possible without "overaging" (loss of ductility and initial high strength), and whether it can be achieved with solid solution alloys hardened with titanium, the present favorite for service up to 1300° F., was unanswered, because the discussion veered off into the reasons for the annoying variations in mechanical properties that plagued their developmental stages. Scott thinks that the expectations had been unfortunately conditioned by our experience with the S.A.E. alloy steels. He contrasts these with austenitic alloys. Fine grain size and freedom from large directional differences are controllable in low-alloy steels by work and heat treatment; the austenitic steels have none of the transformations of ordinary steels to aid in any recrystallization. Furthermore, in the ordinary alloys the nonmetallic matter (oxygen) is controlled by the carbon necessary for strength; carbon is kept low in the preferred "superalloys", and hence oxygen (and nitrogen) must be kept out of the melt else they will react with titanium, locking up uncalculable amounts of this hardening element.

Substitutes for blast furnaces and high grade ores

CANADIAN steelmakers are proud of the fact that the Dominion's production of 3,000,000 tons gives it sixth rank among the countries of the world. Canadian politico-financiers seem to be correspondingly worried about the fact that most of the necessary iron ore and cokemaking coal is imported from the U. S., with consequent drain on dollar exchanges (although a better use for the money is not often suggested). All this is responsible for the interest at Ontario Research Foundation in utilization of iron ore concentrates, low-strength coke, and reduction processes depending on electricity for heat and natural gas for reducing agent. P. (for Pat) E. Cavanagh, assistant director of the Foundation's department of engineering and metallurgy, has studied these problems long and intensively, and believes that the blast furnace is beyond competition from any known operative process in any marketing region requiring over 600 tons of new iron a day. If there isn't any coking coal handy, haul it in. Preference in regions where there is surplus or off-peak electric power, and the market absorbs *less* than 600 tons per day, will either be electric pig or 90% sponge iron from the well-tried Swedish process (Wiberg-Soderfors). Dozens of "direct iron" processes were studied, and Cavanagh concludes that only

the brick kiln has made direct iron commercially, yet it is so wasteful of heat and labor that it is only a quick means for getting additional melting stock in a region where continuous brick kilns are idle and at a time when there is a scrap shortage. (That just about disposes of the sponge iron matter, although of course it will not discourage the inventors.) In this process, a mixture of fine ore and coke dust is charged into saggers and pushed through a tunnel kiln with proper temperature zones. . . . . In the study of taconite concentrates, metallurgists at Ontario Research Foundation have arrived at interesting conclusions by applying modern techniques to outmoded processes. For example, magnetic concentration is preferably done wet, to suppress dusting, yet in a proper alternating field the dry iron particles can be made to dance, thus acquiring the essential motion of jigs and tables used for concentrating copper ores. Again — blast furnace feed, made in the past by extruding moistened fine concentrates through a brickmaking machine (standard and economical equipment) has required subsequent drying, which is costly in time, heat and space. CAVANAGH has found that successful briquettes of this sort can be produced so that no preliminary drying or burning is needed; they must have a strong binder (either inherent or added) and correct porosity so the components can expand as the briquettes enter the hot reduction zone. Taconites, or rather magnetic concentrates therefrom, seem to be quite variable — region to region — in such response to heating.

ANY RECENT BOOK about heat treatment will disclose that a given steel (for example, 4340) tempered at a definite temperature (say 1000° F.) will have a certain hardness: Rockwell C-38, C-42, C-37, C-39 (to quote the first four books consulted!). By itself, each of these "typical" or "nominal" values has a precise look about it; the four together — all different — inspire some skepticism and invite inquiry as to the range of values actually encountered. Back in the days when tempering was called drawing, "typical" values may have been good enough, but the time is fast approaching when something better is likely to be available. That something will be a series of graphs or tables complete enough to define the uncertainty involved in tempering. Hardenability has been tied down by H-bands for several years now, and we may confidently anticipate that temperability will be the next characteristic to have its limits determined. . . . . . . Confidence in this matter will come from a perusal of the article by R. D. Chapman and W. E. Jominy on p. 491. They tempered a series of end quenched hardenability bars (most other metallurgists would say "Jominy bars") and measured tempered hardness in relation to as-quenched hardness along the bar. Then, using the H-band as an indication of hardness variations among numerous heats before tempering, they worked out the limits of tempered hardness for all heats falling within the H-band. Finally, they converted the results to hardness limits at various locations in cylindrical bars of different diameters, and presented a table that supports definite statements such as: "In a 1-in. diameter part made of 4063H steel, tempered at 800° F., the hardness at the center may vary from Rockwell C-34 to 46." The authors explain that their summary tabulation represents the *best* hardness control for *ideal* heat treating conditions; the usual temperature variation of ±20° F. would increase the spread to Rockwell C-33 to 47 for the example quoted. This spread of 14 points is equivalent to that produced by a change of 325° F. in the tempering temperature for a single sample — a fact worth knowing if a part must be tempered so as to exceed a certain minimum hardness at the center. . . . . . . Besides providing accurate data on six widely used steels, the article by Chapman and Jominy will very well serve as a future model for investigating many more of the 77 steels for which H-bands are available. In addition, the article has certain broader implications as regards test results in general: It reinforces the suspicion that handbook or catalog values of properties are often less accurate than would be inferred by counting the number of "significant" digits. This, of course, is a general matter, not limited to alloy steels or to hardness data. A number like "82,000 (typical value)" is always less informative than 70,000 ± 18,000, because the metallurgist cannot know what range may be lurking undisclosed behind the value for typical or average. If the range is broad, it would be especially important to know how broad; if narrow, it would be comforting to have specific reassurance.

Hardness after tempering

"Typical" values

Effect of Residual Stresses on Fatigue of Compressor Valves

By E. W. P. Smith
Consulting Metallurgist
Rocky River, Ohio

RESIDUAL STRESSES due to heat treatment may cause a steel part to fail prematurely. A. L. Boegehold's articles in the February and March issues of *Metal Progress* cited several pertinent examples. To these may be added another in which great improvement in service life resulted from decreasing the residual tensile stresses in the discharge valves of an air compressor.

These valves are blanked from 1065 spheroidized steel sheet 0.062 in. thick, ball burnished, flattened, heated in a controlled-atmosphere furnace, quenched individually in oil and tempered to Rockwell C-44 to 48, then ground and lapped. This gives a finished valve 0.059 in. thick and 0.868 in. square (Fig. 1).

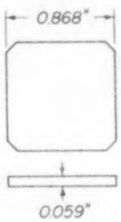


Fig. 1 — Original Valve. Life: 1,380,000 cycles

These disks act as check valves over the pistons of a reciprocating air compressor, permitting the air compressed by the piston to discharge into the compressed air reservoir. On the upward stroke of the piston the valve opens, hitting against a stop; then as the piston reverses and goes downward the valve closes against the valve seat. This operation is a fairly simple fatigue test, and our procedure for evaluating performance of the valves is to run sample parts in a standard compressor operating at 3600 r.p.m., which is 1600 r.p.m. faster than the recommended maximum speed.

Although only a small percentage of these valves had failed in service, it was decided to redesign the part for indefinite life. The effect of hardness was checked by testing valves heat treated to Rockwell C-62 to 65 and C-26 to 27. Valve life was considerably less at both these hardnesses than at the usual Rockwell C-44 to 48. Changing the thickness from 0.059 to 0.077 or 0.044 in. was not beneficial. Tumbling the parts for 24 hr. did not remove the deleterious effect of the sheared edges. Test life was increased only 25% by sanding the sheared edges in order to eliminate stress raisers.

Valves which had been austempered or martempered to the same hardness as the conventionally heat treated parts showed a marked increase in ductility, but a decrease in fatigue life. This was surprising because the thin section of these valves would seem to make them ideal for an interrupted quenching treatment. A group of valves was sent to a prominent salt manufacturing concern for austempering, and these outside tests confirmed our own.

Many different materials were tried. These included plain carbon and alloy steels, nonferrous alloys, and both austenitic and martensitic stainless steels. Changes in material did not improve the valve life.

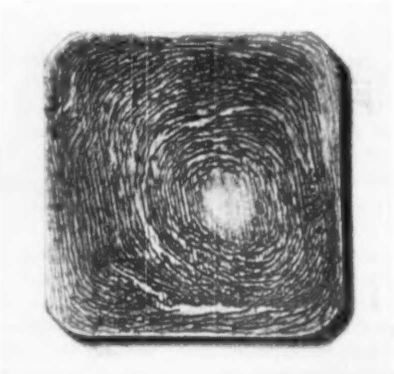


Fig. 2 — Original Valve Etched to Show the Pattern of Quenching Stresses. 2.4×

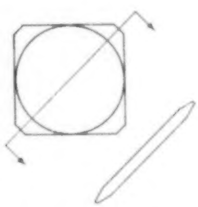


Fig. 3 — Redesigned Valve. Life: 21,600,000 cycles

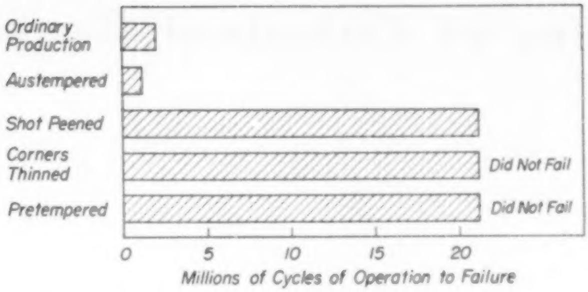


Fig. 4 — Comparison of Fatigue Life of Various Discharge Valves Tested in a Standard Compressor at 3600 R.p.m.

It was then decided to investigate the stresses in the part due to heat treatment. First a brine quenched valve was etched in a solution of sulphuric acid to reveal, qualitatively, the stress pattern caused by quenching. The sensitivity of highly stressed metal to chemical action is well known; the phenomenon of stress-corrosion cracking (as in the "season cracking" of cold worked brass) is perhaps the best example of this sensitivity. Cracks caused by corrosion or etching are approximately perpendicular to the predominant direction of tensile stress. Thus, the crack pattern shown in Fig. 2 indicates a high concentration of tensile stress at the corners of the valve. (The eccentricity of the pattern is due to a somewhat uneven quench; it is practically impossible to quench each of a large number of these small parts identically.)

Stress relieving at 550° F. for 2 hr., after the grinding and lapping operations, improved the valve life 300%, but this was still short of the goal of indefinite fatigue life. It was thought that if the corner stresses could be eliminated this goal might be reached. Round valves were therefore tried, but they showed no improvement over the square valves. Apparently the edges of the valves had residual tensile stresses about as great as at the corners of square valves. It was then decided to remove the highly stressed metal from square valves by grinding the four corners to one third of their thickness, as shown in Fig. 3. These valves ran 15 times as long on test as the untapered valves and then did not fail. This was 21,600,000 cycles (Fig. 4 and 5) and was considered satisfactory performance.

To add further emphasis to the belief that the life of this part could be greatly increased by eliminating the corner stresses caused by heat treating, valves cut from pretempered stock were tested. As this pretempered strip had been heat treated to Rockwell C-50 at the mill, there was no stress concentration at the corners of the individual pieces cut from the strip later. These valves did not fail after being tested 15 times as long as the ordinary valves. (In these particular valves the corners were not tapered.)

As the residual heat treating stresses were tensile stresses, they added to the stresses placed on the material in operation and thus caused failure long before it would occur if only the operating stresses were present. Since shot peening introduces compressive stresses in the surface, shot peened valves were also tried. They were peened with S-170 shot to intensities of 0.007 A_2, 0.009 A_2 and 0.011 A_2. ("A_2" refers to the type of Almen gage used to measure the intensity of shot peening.) As the intensity was increased the valve life increased, until at the 0.011 A_2 intensity the life was 15 times that of the original valves.

The etching test was applied to shot peened, pretempered and corner-thinned valves, in the same manner as with the original valve. Unlike the original, which cracked badly in this test (Fig. 2), these other samples, all of which had satisfactory fatigue life, showed no noticeable crack pattern after etching.

Summary — The residual quenching stress plus the operating stress caused failure in the original production valve. When these residual tensile stresses were minimized or eliminated by thinning the valve corners, the magnitude of the operating stresses alone was below the fatigue limit in an accelerated service test, as shown schematically with reference to the S-N curve of Fig. 5.

The corner-thinned valves were adopted as standard production two years ago, and no field failures have been reported since.

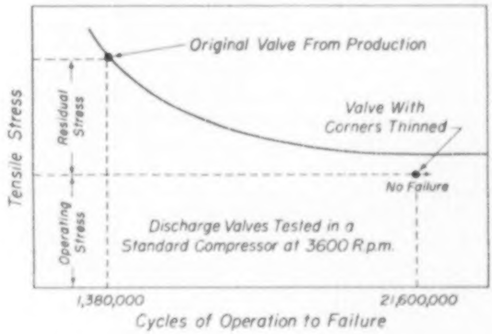


Fig. 5 — Semi-Schematic Diagram Showing How Residual Tensile Stress Adds to Operating Stress to Cause Fatigue Failure After Relatively Short Service

Quenching of Carburized Gears

By S. L. Widrig
Chief Metallurgical Engineer
and Wilson T. Groves
Metallurgical Engineer
Spicer Mfg. Division of Dana Corp.
Toledo, Ohio

Compared with the expert study given other principal factors in case hardening, quenching has been almost neglected. Nevertheless it is one place where much trouble can arise. Particularly in the hardening of gears, distortion is a large problem, often kept under control only by using accurate quenching fixtures in powerful presses — a slow and labor-expensive process. Quenching in an open tank is far more in keeping with mass production ideas; many of its limitations can be removed if proper mechanization eliminates the human variable.

PROBABLY in no other industry is the maintenance of physical dimensions during heat treating more important than in the manufacture of gears by the process wherein the gear teeth are cut and shaved "in the green" with no subsequent grind after carburizing and hardening. It is also probable that no other phase of metallurgical processing is more important in controlling dimensions than quenching technique, although such considerations as forging grain flow, residual stresses from cold working or prior heat treatment, method of loading trays and fixtures, geometry of part, and uniformity of heating are also of major importance. Despite the importance of quenching techniques, little can be found about it in the technical literature in comparison with the ample discussions of such things as "grain" and "fiber", prior heat treatment, and geometry of part. It will be our effort in this article to describe the more-or-less conventional quenching practices in long use at Spicer Mfg. Division of Dana Corp. listed as No. 1 and 2 below, and in a subsequent article to give a fuller account of the satisfactory development of a more economical practice, item No. 3 below, a modified "martempering" process.

Quenching methods can be classified into three divisions, namely:

1. Plug and press fixture quenching.
2. Quenching in open tank.
3. Martempering, or some modification thereof.

These items will be discussed primarily from a production standpoint with as little space as possible allotted to theory. The carburizing furnaces used by us have already been described in *Metal Progress* for August, 1949.

All the furnaces are continuous pusher type, heated by radiant tubes, but are of two sizes using two different heat cycles, namely, direct quench and reheat. Axle parts such as ring gears, pinions, side gears and pinion mates are carburized in two-zone furnaces containing two rows of 15 x 19-in. trays and are quenched directly from the carburizing temperature. The work is in the furnace for approximately 7 hr. and the desired case depth of 0.040 to 0.050 in. is produced with temperatures of first and second zones maintained at 1700 and 1650° F. respectively.

Most of the heavy-duty transmission gears and shafts manufactured at Spicer are carburized in four-zone furnaces containing three rows of 16 x 21-in. trays. It takes approximately 11 hr. for the work to pass through these furnaces, and a case depth of 0.040 to 0.050 in. is obtained with the following temperature cycle: a heating zone and a carburizing zone both maintained at 1725° F., a cooling zone at 1150° F., and a reheating zone at 1550° F. Special devices are installed at the

quenching end, depending upon the quenching medium utilized (as will be evident in the sequel).

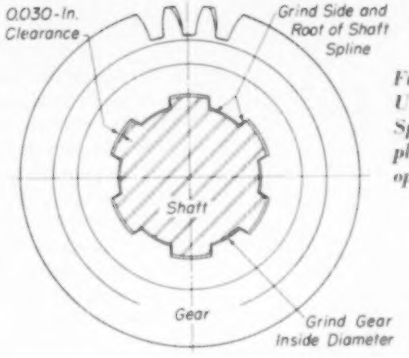


Fig. 1 — Amount of Finish Grinding Usually Necessary on Straight-Sided Spline of Gear and Shaft. Gear is plug quenched; shaft is quenched in open tank. Both are carburized jobs

Quenching Mediums — Practically all the gears currently used in the automotive and allied industries are made from oil hardening alloy steels and none of the more drastic quenching mediums such as water, caustic, or brine, will be considered here. The slower cooling rates obtained with oil, of course, decrease the temperature gradient in the cooling part from surface to center, and consequently minimize the tendency to distort or crack during hardening. Oils commonly utilized for quenching are relatively inexpensive mineral oils with a flash point of approximately 375° F. and a Saybolt viscosity of 100 sec. at 100° F. Temperature of the bath in the range of 120 to 160° F. appears to give optimum results, and the volume of the bath and its natural radiation or its circulation through heat interchangers is so arranged that the heat absorbed from the hot metal will never raise the temperature above 150 or 160° F.

Plug and Press Quenching

In the manufacture of transmission gears it is necessary to maintain close fits between splined sliding gears and shafts in order to decrease backlash in the gear sets. For gears with straight-sided splines, the specified dimensions are usually obtained by plug quenching followed by grinding of the surfaces indicated in Fig. 1. For gears with involute splines, it is common practice to finish machine in the green and quench on a plug that contacts the root of the gear spline. The outside diameter of the mating shaft is ground to blueprint dimensions after heat treatment.

A typical example of plug quenching is illustrated in Fig. 2 — a small clutch gear with an involute spline that is quenched over the plug shown at the left. The plugs are sometimes made from high speed toolsteel, but more frequently from a low-alloy steel such as 4620 or 4320, carburized and hardened, and ground to desired dimensions. (The hard, wear resistant surface is required to prevent scuffing, and to minimize dimensional changes during use.)

It is necessary to develop each new job to determine the proper broach size for green cutting and the plug size for hardening. The partial relief of residual stresses during the 340° F. draw (which is the usual practice at Spicer) usually results in a shrinkage of 0.0005 to 0.001 in. in the bore diameter and allowance must be made for this. Different heats of steel do not always quench out the same, so several plug sizes must be available for each job so that proper finish dimensions will always be obtained.

Because of thermal expansion, it is of course an easy matter to drop the hot gear over the cold plug prior to quenching. After quenching, however, the plug must be pushed out by a pneumatic press. If the plug can be removed from the gear by hand, it is often an indication that the gear was broached oversize and the plug served no useful purpose.

Press quenching is another means of controlling dimensions during hardening, and the intricate machines developed for this process demonstrate the ingenuity characteristic of the American machine tool industry. In this method, the hot gear is placed on the bottom die of a pneumatic press; the upper die then comes down and presses the gear flat while it is still in a hot plastic condition. The clamped gear is completely immersed in oil almost instantly after the quenching cycle is started and the dies are designed with many small

Fig. 2 — Plug (Left) Which Is Introduced Into Bore of Gear for Dimensional Control During Quenching

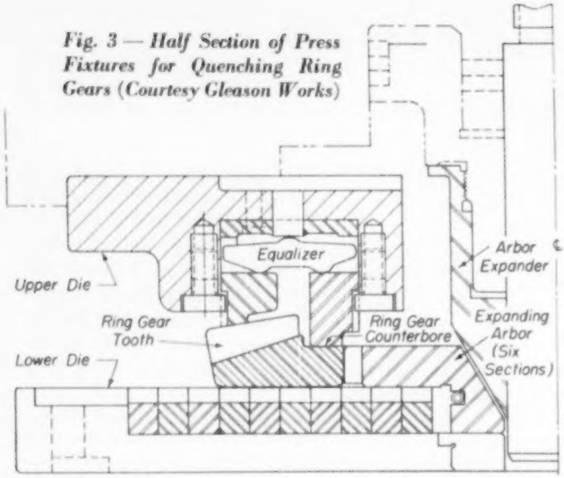


Fig. 3 — Half Section of Press Fixtures for Quenching Ring Gears (Courtesy Gleason Works)

passages so that oil (from a recirculating pump and reservoir, built as an integral part of the quench press) is forced uniformly around the gear while it is held flat in the press. The quench cycle is predetermined and automatically controlled to give the desired results. (When large transmission gears with an internal spline are being quenched, a plug similar to the ones described in preceding paragraphs is usually attached to the bottom die in order to align the spline properly with the gear teeth.)

Although various types of presses and dies are used, one of the most popular is the Gleason press used for quenching automotive ring gears. Figure 3 is a half section showing how the ring gear is held between the upper and the lower die. During the machining operation, the back face of the green gear is ground and the teeth are cut after locating on this ground face and the broached bore. The expanding arbor of the lower die of the quenching press also locates on the bore and aligns the gear. The ground face contacts the lower die, and the upper die contacts the top of the gear teeth and the counterbore.

All the ring gears made at Spicer are of carburized 8620 steel and the gears must be flat within 0.002 in. after hardening. Although the gears are quenched drastically enough to give a Rockwell hardness of C-40 to 42 in the core of the tooth at the pitch line, and C-38 to 40 at the root, only a small fraction of 1% is rejected for distortion. It is important that the ring gears as well as pinions have a file-hard surface to resist scoring and a microstructure in the core that will give required strength and fatigue properties.*

Limitations of Plug and Press Quenching

Both plug quenching and press quenching have the obvious disadvantage of imposing a serious limitation on the production that can be obtained from a furnace. Each part must be handled individually and only a few parts can be placed on any tray that is withdrawn from the furnace, if the last part handled is not to become too cool before quenching. A method of circumventing this difficulty in the hardening of ring gears was described in our article in *Metal Progress* last August. Briefly, it consists in building a small exit corridor through the end-wall of the furnace

*This involves having the quenching temperature high enough and cooling rate rapid enough to prevent separation of massive ferrite in the core.

Fig. 4 — Forty-Four Carburized Rear Axle Pinions Weighing 250 Lb. May Be Successfully Hardened in Oil Bath, if the Stream of Oil Is Vigorous and Properly Directed. (A copper cap with internal threads is first screwed over the spline end of the pinion. A pin, inserted through the hole in the cap, or a stirrup, bearing against its shoulder, suspends the pinion vertically in the fixture. The copper cap keeps the threaded end soft after the carburizing and quenching cycle)

and protecting its door with an efficient gas curtain. The last trays within the furnace are handled by transfer and elevating mechanisms, so that ring gears are presented to the inner end of the exit corridor one by one, as the quenching presses demand.

Considering the low productivity obtained by plug and press quenching and the high labor cost for individual handling of the parts, an alternate method of controlling distortion during quenching is obviously very desirable. It might also be expected that such a method could be used to obtain improved results for many parts that are now open tank quenched in the conventional manner next to be described. Such an alternate has been studied quite intensively by Spicer's metallurgical department, and it will be discussed in the article next month.

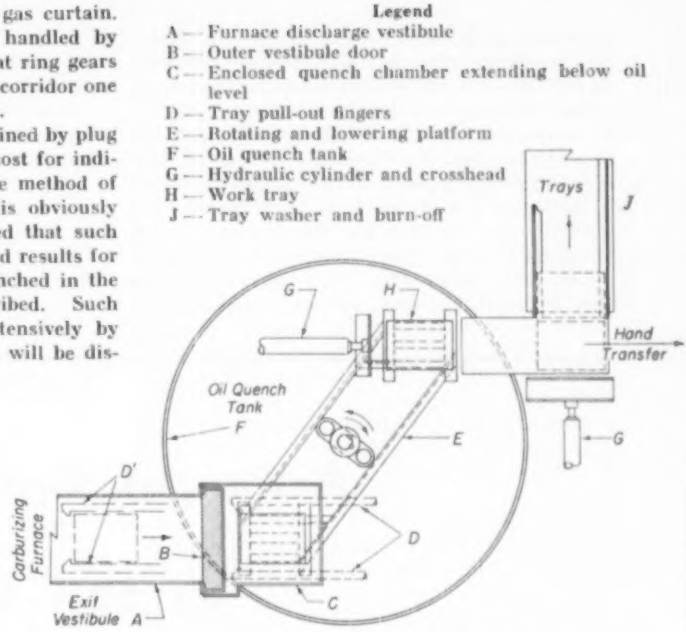


Fig. 5 — Automatic Quenching Mechanism Used With Continuous Gas Carburizing Furnace (Courtesy Surface Combustion Corp.)

Open Tank Oil Quenching

As is well known, more parts are quenched by simply immersing them in a tankful of liquid than by all other means put together, and this includes carburized parts of all sorts. Open tank quenching is so widely employed because of its simplicity and high productivity, particularly in the hardening of dense loads. From a quality standpoint it should be emphasized that *consistency* is the keynote to success. Too much thought cannot be given to uniform loading of the work on trays and fixtures and adequate flow of the quenching liquid, so directed to give uniform results throughout the load. When oil is the quenching medium, its physical properties must be carefully maintained. In the latter respect, the use of a centrifuge for removing water and sludge from the circulating system gives highly satisfactory results.

A good example of this type of quenching is the hardening of automotive rear axle pinions of carburized 8620 steel. Here, 44 pinions comprising a 250-lb. gross quenching load are suspended head down from a rack as shown in Fig. 4 and carried through a gas carburizing furnace on a 15 x 19-in. tray. When the loaded tray is discharged from the furnace, the rack is lifted from the tray and lowered into a quench tank where a stream of oil from a 250-gal. per min. pump is directed upward through the load. Despite the density of the load, it is an easy matter to obtain pinions that are consistently file-hard on the surface and have a hardness of C-36 to 40 in the core at the pitch line of the tooth.

Although the changes in tooth form taking place during the quench are minimized with the above procedure, some variations exist between different heats of steel. It is well to harden a pilot lot of pinions from each new heat of steel and run these on a test stand with a standard ring gear to check the location of tooth-to-tooth contacts. Variations from heat to heat are compensated in the green cutting of the pinion teeth and no changes need be made in the ring gear cutters.

New designs in automatic quenching equipment have eliminated the human variable from the quenching operation. An automatic "lowerator", shown schematically in Fig. 5, operates in conjunction with a furnace used for gas carburizing transmission parts and has been a great asset in insuring consistent results from day to day. Its operation is briefly as follows:

The furnace door *B* is raised; pull-out fingers *D*, *D'* move the loaded tray from the furnace vestibule *A* into a completely enclosed quench chamber hood *C* and onto a platform of the lowerator *E*. The platform is then lowered into the oil and, after reaching the bottom of the tank, it is rotated 180°. At the start of the next furnace cycle, the lowerator is raised and the loaded tray *H*, now cold, is automatically moved onto another platform where the work is removed manually and hooked on trolley conveyers of a spray-type washer and recirculating draw furnace. The empty tray, with any con-

tained fixtures, is then pushed through a washer and low-temperature burn-off furnace to remove the oil. Another platform on the lowerator, located at 180° from the one described, is then in position to receive the next loaded tray from the furnace.

The enclosed chamber above the quench tank is continuously purged with a prepared atmosphere which protects the work from contact with air from the time it leaves the furnace until it enters the quench. This procedure insures against a soft, decarburized skin. The work emerges with only slight discoloration, thereby eliminating the costly shotblasting process after heat treatment.

Although the quenching method indicated in Fig. 5 with its associated auxiliaries has proved economical and practical in the hardening of transmission gears and shafts without undue distortion, it has been found that further improvements can be effected by a modified martempering process using special quenching mediums. Such a process has been adapted to many parts that have previously been quenched over plugs or in presses, with such success as will be described in our following article.

Action of Corrosion and Stress on 13% Cr Stainless Steel

By H. H. Uhlig
Corrosion Laboratory
Department of Metallurgy
Massachusetts Institute of Technology

EDITOR'S INTRODUCTION: Few metals or alloys are immune to stress corrosion. Brass "season cracks". Tough steel boiler plate, cracking in service without apparent ductility, is said to be suffering from "caustic embrittlement". Commercial production and use of some aluminum alloys have been handicapped by the necessity for controlling susceptibility to stress corrosion. Expensive failures of stainless steel equipment have been traced to it. As far as fundamental principles are concerned, it is generally agreed that the cracks originate in surface regions carrying a steady tensile stress (either from the loads the parts are designed to carry, or from stresses remaining from previous treatment during fabrication); also that the stress must be above a certain minimum, and that there must be a corroding medium in contact with the surface for a sufficient time. The user's problem is to inhibit, in some way, the activity of the corrosive surroundings. [From here on, the article is Dr. Uhlig's.]

Stainless Steels — As a matter of fact, the mechanism of stress corrosion cracking in the stainless steels and the factors of the alloy that influence it are still relatively unknown. For stressed 18-8 Cr-Ni steel, previously quenched from a high temperature, it seems that a slightly acid chloride solution is specific for transgranular fracture. [A favored laboratory test is boiling in 42% $MgCl_2$ solution.] It is reported that nickel and carbon content of the alloy influence susceptibility to this type of failure, and also the relative ease with which the alloy transforms from austenite to ferrite on cold working.

The ferritic stainless irons (17% Cr is typical) seem to be more resistant than the 18-8's to stress corrosion cracking in slightly acid chlorides, as was pointed out by Merrill A. Scheil in the 1944 A.S.T.M.-A.I.M.E. symposium on the stress corrosion cracking of metals. Nevertheless, the martensitic-type stainless steels, such as the 13% Cr alloy, have been reported extremely susceptible to this type of cracking in seawater or in salt spray 20 years ago when they were considered as

substitutes for aluminum alloys for building the skeletons of dirigibles. It now appears probable from experimental evidence recently acquired in the corrosion laboratory of Massachusetts Institute of Technology that at least some of these stainless steels may "stress corrosion crack" (if indeed the failure should be so called) by a mechanism differing from that operating with the austenitic stainless steels.

Information on the cracking of fabricated aircraft spars of martensitic stainless steels was given in 1933 by Paul D. Ffield (then metallurgist for Goodyear-Zeppelin Corp.) in "The Book of Stainless Steels". Recently Mr. Ffield (now superintendent of development and research for Bethlehem Steel Corp.'s shipbuilding division) sent to us an old sample of hardened and cold worked 13% Cr stainless steel sheet containing copper and high in silicon (12.5% Cr, 0.10% Ni, 0.12% C, 1.2% Cu, 1.2% Si). It had a Rockwell hardness of C-47.

The sheet, measuring 0.019 in. thick, was sheared by us into 5 by ¼-in. strips; these, in turn, were bent into U's of about 1½-in. radius and held in slotted plastic holders. One specimen so stressed was immersed in distilled water. At the end of six months, this specimen remains unattacked in any sense of the word. Two other similar specimens were immersed at the same time in a 3% solution of common salt. Rusting and slight pitting soon occurred, particularly near areas of contact with the plastic holders (crevice corrosion), but only after 4½ months did one specimen finally crack. The other is still intact after six months.

Since this identical material was found some years ago to be very sensitive to stress corrosion cracking in salt water, conditions were explored under which it might now crack in shorter time. One specimen stressed as above was coupled to a sheet of aluminum foil measuring about 25 sq.in., and submerged in 3% NaCl solution. With this arrangement the stainless steel strip cracked overnight.

Aluminum is anodic to stainless steel in 3% NaCl, and this experiment suggested that cathodic polarization was the critical factor causing rapid failure. This proved true in experiments whereby several stressed specimens were arranged as cathodes of a cell permitting hydrogen to discharge on the stainless specimen's surface. Electrolyte was again 3% NaCl solution, the anode platinum. When the cathodic current density was 0.08 ampere per sq.in., a specimen broke spontaneously in 2¾ min. At a current density of 0.05 ampere per sq.in., another specimen also broke, but the time required was longer.

Using dilute sulphuric acid containing a few drops of white phosphorus dissolved in carbon disulphide to accelerate hydrogen adsorption by the alloy, cracking occurred again within about 2½ min.; the current density, however, was now 0.02 ampere per sq.in. Unlike brief exposure to sodium chloride solution, immersing the stressed alloy in sulphuric acid (omitting the impressed current) also caused cracking within a few minutes. Local cell action was apparently sufficient to cause adsorption of hydrogen.

These experiments suggest that so-called stress corrosion cracking of this martensitic-type stainless steel may occur under any condition that favors discharge of hydrogen ions on the surface. Hydrogen entering the alloy lattice apparently induces stresses of a magnitude sufficient to initiate a crack, which — aided by existing stresses — then propagates itself throughout the cross section of the specimen.

It was observed that the stainless specimens after brief cathodic polarization in NaCl or H_2SO_4 are exceedingly brittle, but that on standing again in the air the usual ductility is regained. This behavior is typical of hydrogen embrittlement.

The phenomenon of hydrogen embrittlement is not unusual, but it is less common for an alloy to crack *spontaneously* by hydrogen adsorption — particularly where current densities are no greater than those that occur with aluminum coupled to stainless steel in sodium chloride solution. For example, a piece of spring steel, of Rockwell C-50 hardness, of the same approximate dimensions as the 13% Cr steel samples and stressed identically did not crack after 16 hr. cathodic polarization in 3% NaCl at a current density of 0.01 to 0.02 ampere per sq.in. Likewise, a piece of cold worked 18-8 (titanium stabilized) was immune to cracking under similar conditions when constantly polarized over a period of four days.

Some investigations published by the writer in 1944* indicate that hydrogen diffuses less readily through ferrous alloys of face-centered cubic lattice (austenite) than through body-centered cubic (ferrite). However, other factors must also enter into failure of the martensitic 13% Cr alloy, in view of the fact that spring steel (also martensitic) does not fail similarly.

These experiments suggest that failure by cracking of the stressed martensitic stainless steels exposed to a corrosive environment under conditions similar to those described above may probably best be described as "hydrogen embrittlement".

*H. H. Uhlig, *Transactions* of the A.I.M.E., Iron & Steel Division, Vol. 158, p. 199.

Correspondence

Thermal Polishing and Etching of Nickel

Los Alamos, N. M.

In the course of an experiment dealing with the recrystallization and grain growth of high-purity nickel, it was noted that the unpolished and unetched surfaces of the specimens became polished and etched during an anneal of 25,000 min. (17 days, 9 hr.) at 900, 1000 and 1093° C. (1650, 1830 and 2000° F.). The specimens were contained in sealed quartz tubes evacuated to one micron of mercury.

A survey of the available literature indicates that Lustman and Mehl (*Transactions,* A.I.M.E., Vol. 143, 1941, p. 246) were the first and only investigators to have noticed this phenomenon heretofore. They observed that fine scratches were removed from the surfaces of polished single crystals of copper as a result of annealing the crystals at 900 and 1000° C. for 12 hr. in an atmosphere of hydrogen.

The polishing and etching is the result of evaporation (sublimation) of metal from the surface of the specimen. Apparently, the rate of evaporation of the nickel is greater in areas where the curvature is greater, such as areas adjacent to scratches or to the intersections of the grain boundaries and the exterior plane surfaces of the specimen. The process of sublimation eventually results in the elimination of scratches and in the relief etching of the grain boundaries, as shown in the accompanying micrographs. An examination of the inside of the quartz tubing which held the nickel specimens during annealing revealed a very small quantity of nickel.

Although the phenomenon described here is mainly of academic interest, it may provide a feasible method for obtaining metallographic data concerning high-temperature allotropic phases such as those of iron, titanium and uranium.

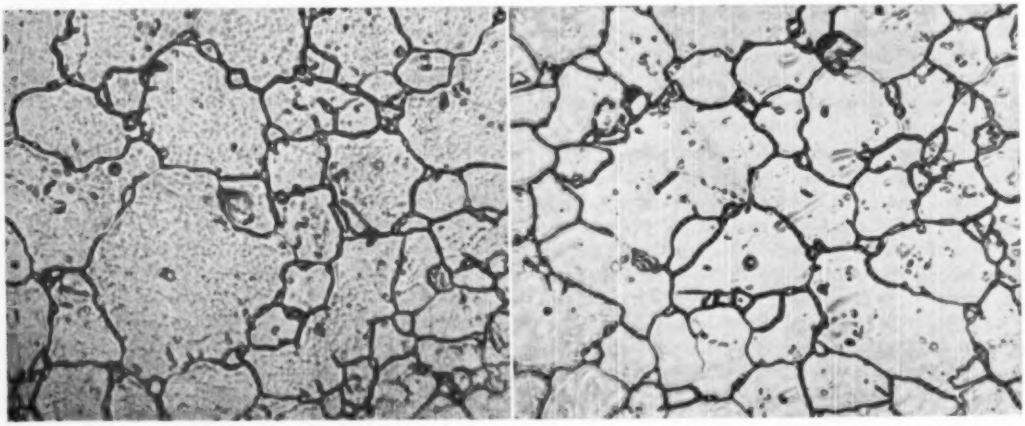
Glen W. Wensch
Los Alamos Scientific Laboratory

Aluminum Coating of Steel

East Swanzey, N. H.

Messrs. Stroup and Purdy have presented an excellent comparison of various processes for coating aluminum on steel in *Metal Progress* for January. I have one unfavorable comment to make:

From their Table II on page 63, it would seem that metallizing is rated, cost-wise, as being the most expensive method of applying aluminum. The authors note that the ratings were based on prices quoted for commercial jobs, but there seem to have been some factors omitted which might well have altered the conclusions.



Two Nickel Specimens Polished and Etched by Vacuum Annealing for 17 Days, 9 Hr. at 2000° F. Magnified 40×

First, in actual practice, the cost of metallizing (spraying) with aluminum for resistance to *heat* oxidation is not usually compared with the cost of calorizing, because metallizing is most frequently used on articles that are much too large to be calorized economically or practically. I have reference to such articles as salt and cyanide pots, annealing covers, melting and pouring pots, and crucibles.

Second, the cost of applying aluminum for resistance to various forms of *atmospheric* corrosion is likewise a matter of the specific application. Our experience indicates that metallizing is most frequently used on structures that are either too large to be handled by other methods, or on structures and fabrications that are already in service. For instance, one of the largest jobs on record is being done in Great Britain, involving the coating of some 50,000 tons of structural steel with aluminum. The cost of metallizing was thoroughly compared with other practical methods, and metallizing proved much less expensive.

The average contractor seldom is called on to apply aluminum to flat sheets or large quantities of small parts; rather, he is called on to coat large assemblies or structures either during or after fabrication.

With such factors as this in mind, it is our opinion that cost comparisons on a blanket basis are likely to be unintentionally misleading.

W. C. Reid
Consultant
American Metallizing Contractors' Assoc.

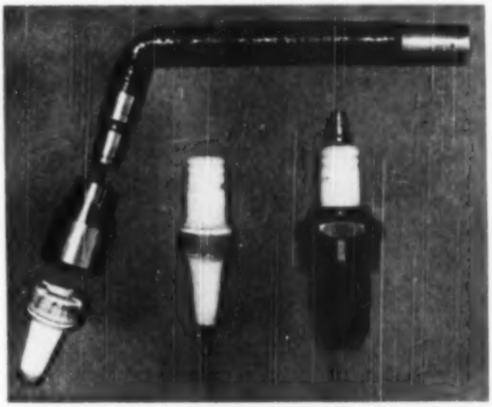
Dr. Stroup Replies

Mr. Purdy and I agree with Mr. Reid that under present conditions metallizing is the most frequently used method and in most cases the only possible method of applying a metallic coating to structures already erected or to very large structures. We use metallizing extensively in our own operations. Quotations and costs on this method that we have experienced have run from $0.75 to $1.00 per sq.ft., which we consider to be high. We know of one company that is coating steel boiler tubes 20 ft. long with aluminum by hot dipping.

Porcelain Nozzle for Inert-Arc Welding

Amarillo, Tex.

The welding equipment and electrode holders generally available for inert-gas-shielded arc welding have been designed for average welding applications involving high welding currents. The electrode holders and ceramic nozzles, while satisfactory for most applications, are cumbersome and difficult to use for small intricate jobs. Experimental work at the Amarillo Helium Plant on the helium-shielded arc welding of thin sheet metals required a small porcelain or ceramic nozzle that could be used with $\frac{1}{16}$ or 0.040-in. tungsten electrodes. The problem was satisfactorily solved by adapting the porcelain insulator of an old spark plug to form a nozzle for a small manual electrode holder. The porcelain insulator in the average



Disassembled Porcelain Nozzle for Inert-Arc Welding

spark plug is of high-grade porcelain designed for high temperatures and voltages. These characteristics are prerequisite for a good porcelain or ceramic nozzle.

In making a small nozzle from a spark plug, the porcelain was removed by chucking the plug in a lathe and turning off the metal collar. The insulator was then cut in two just above the large shoulder by using a silicon carbide grinding wheel. The spark plug electrode is usually cemented or molded to the upper half of the porcelain so that when the insulator is cut in two the electrode is easily withdrawn from the lower section.

Four grooves, $\frac{1}{8}$-in. deep, were ground at 90° on the back face of the porcelain for gas ports (see photograph). A stainless steel adapter was turned to fit the porcelain cap to the electrode holder. The finished porcelain nozzle shown in the photograph is small — $1\frac{3}{8}$ in. long — and convenient to use. It provides good arc stability since the inert gas is directed close to the electrode. The nozzle orifice is small — $\frac{3}{32}$-in. diameter — and thereby conserves gas and allows a smaller gas flow. The porcelain nozzle will not arc across the electrode or short the electrode to the work. It is small enough to use in many confined spaces.

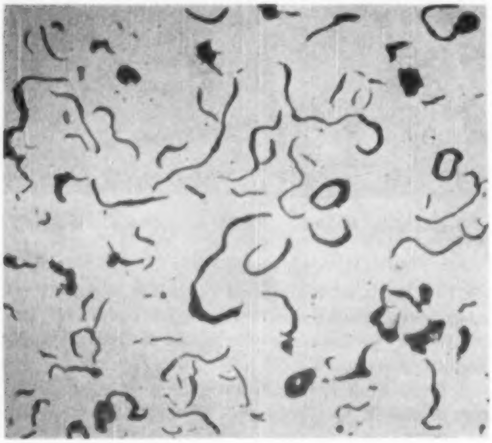
An electrode holder used with the small porcelain nozzle described above will facilitate the welding of thin-gage metals and will provide a means for welding intricate work that is impossible to weld with conventional nozzles.

William A. Mays
Metallurgical Engineer
U. S. Bureau of Mines

Circular Graphite in Cast Iron

Birmingham, Ala.

With all the furore over nodular graphite, spheroidal graphite and spherulitic graphite in cast iron, we feel that it is time to disclose our exclusive development of circular graphite cast iron. (See accompanying micrograph of an



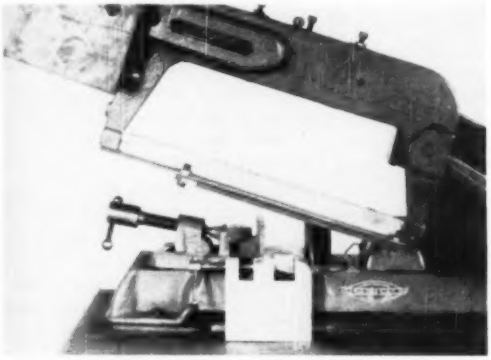
unetched specimen at 250×.) Please remember that this development is in its infancy. Among the aspects of our circular graphite cast iron still to be worked out are: How to make it again, what to use it for, and why make it at all.

C. K. Donoho
Chief Metallurgist
American Cast Iron Pipe Co.

Rapid Production of Small Metal Particles

Chicago

The production of metal particles for use in the X-ray powder method presents a problem if a large number of specimens are needed. Hand filing is laborious and time-consuming. Therefore, some automatic means to produce these particles is desired. One convenient method is to convert a small power hack-saw into a filing machine by replacing the hack-saw blade with a jig for holding the file. This jig is merely a piece of angle iron to which the file may be fastened. The accom-



panying photograph shows the equipment modified for filing purposes. If the metal sample is fairly small, it may be held in place by an auxiliary vise, as shown in the foreground of the photograph.

In laboratories where numerous powder specimens must be prepared, the expense of this equipment is readily justified by the time saved.

G. F. Tisinai and R. B. Hendry
Engineering Research Department
Standard Oil Co. (Indiana)

Carbide Cat

Chicago

We found this carbide cat and small butterfly in a sheet of hot rolled, commercial quality steel. The specimen was lightly etched in picral and is reproduced at 1500× in the accompanying micro.

Byron Zolin
Plant Metallurgist
Hotpoint, Inc.

Hardness Variations in Carbon-Molybdenum Steels After Tempering

By R. D. Chapman
and W. E. Jominy
Chrysler Corp., Detroit

During recent years, hardenability bands have been published for 77 of the standard alloy steels. These bands permit the prediction of hardness distribution (surface to center) and the expected limits (at a given depth) for as-quenched steel sections of various diameters. Comparable information has not been established concerning the hardness distribution after tempering. This article, on six steels of series 4000, provides the first systematic data on tempered hardness as a function of as-quenched hardness — data which permit the authors to make definite statements of the following kind: "In a 1-in. diameter part made of 4047H steel, tempered at 800° F., the hardness at the center may vary from Rockwell C-29 to 38."

NUMEROUS data are available concerning the effect of tempering on the hardness of steel specimens entirely or predominantly martensitic as quenched. But steel parts as quenched in production are seldom fully martensitic. Frequently only 50 to 90% martensite is present at the center of the section, and sometimes the central structure may be mostly bainite and pearlite. For rational design of such parts and as an aid in heat treating them, it is important to know the temperability of structures other than martensite. Ideally, this information should be available for all structures found in the end quenched hardenability bars of the standard steels.

The purpose of the experiments described here is to establish tempering curves for the standard carbon-molybdenum steels (S.A.E.-A.I.S.I. series 4000), showing the decrease in hardness with increased tempering temperature, starting from any as-quenched hardness value.

Hardenability Procedure — The steels used in this study are listed in Table I. Standard end quenched bars were machined from these steels after they had been normalized at 150° F. above their A_3 temperatures. No bars smaller than 1⅛ in. diameter were used and the largest size was 2¾ in. Six hardenability specimens from each composition were machined from the centers of these bars after normalizing. They were heated in cast-iron chips at 75° F. above their A_3 temperatures, and cooled on the standard quenching fixture until cold. Then the bars were ground under solution to a depth of 0.015 in. and Rockwell impressions made on the two opposite sides which were ground. The hardness results so obtained showed a maximum variation of 1½ points Rockwell C among the six bars. Thus, an average hardenability curve for each composition was obtained.

Tempering Procedure — Bars from each steel were tempered at the following temperatures: 340, 440, 540, 650, 750, 850, 950, 1050, 1150, 1200 and 1275° F. Bars tempered at the lower tempering temperatures were again used to obtain hardness values at one higher tempering temperature. A thermocouple was embedded at the 1½-in. position of each of the bars tempered so that the bar temperature and not the furnace temperature was maintained. For the lower tempering temperatures, care was taken to select bars as close as possible to the average hardenability curve. Rockwell impressions were taken on the tempered bars after grinding under solution at an angle of 60° from the original flat. For the three lowest tempering

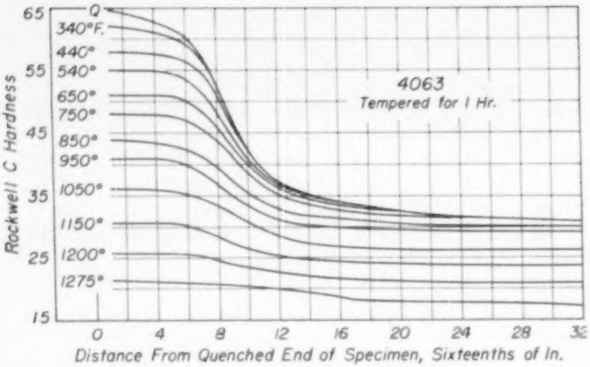


Fig. 1 — Hardness Along End Quenched Hardenability Bars After Tempering

temperatures Vickers hardness was measured because it is more sensitive than Rockwell to small hardness changes. At least two readings were made at each position and frequently further checks also. The final results are based on a total of more than 4000 hardness readings.

Tempering Time — In order to determine the effect of tempering time on the hardness, hardenability bars of 4063 were end quenched from an austenitizing temperature of 1470° F. in the same manner as described above. Thermocouples were welded to the bars at the 1½-in. position. Bars were then placed in a recirculating air furnace and tempered at 900° F. for the following periods: 15 min., 30 min., 1, 2, 5, and 10 hr. Time was measured when the thermocouple welded to the bar indicated a temperature of 890° F. Flats were reground on these bars at an angle of 60° to the original flats and Rockwell readings were taken. Typical results of these tests are shown in Table II. Since 1 hr. at temperature corresponds quite closely to production practice, this time was selected for the remaining tests.

Results — Figure 1 shows the family of curves obtained after tempering the hardenability bars of 4063 steel. The six graphs on p. 492-B record the hardness data for all the steels studied. Figure 2 compares the results obtained by tempering these hardenability bars with data from sectioned 2-in. diameter bars oil quenched and tempered. The results on the 2-in. bars were obtained several years before the other data, by careful quenching, tempering, sectioning and measuring techniques, and the results were checked independently in several metallurgical laboratories outside the Chrysler Corp. The actual results come quite close to those calculated from the present data.

The curves of J. M. Hodge and M. A. Orehoski (A.I.M.E. *Transactions*, Vol. 167, 1946, p. 627) are widely used to predict the approximate percentage of martensite from the as-quenched hardness of steel of a given carbon content. However, these curves do not cover the range from 0 to 50% martensite, which was of considerable importance in the present investigation. Figure 3 shows the variation in amounts of microconstituents along the end quenched bars of steels 4047 and 4063, as

(Continued on p. 493)

Table I — Compositions of Steels Tested

Steel	C	Mn	Si	Ni	Cr	Mo
4027	0.27	0.89	0.28	0.080	0.140	0.23
4032	0.31	0.83	0.27	0.050	0.135	0.24
4042	0.43	0.81	0.28	0.030	0.045	0.22
4047	0.47	0.68	0.32	0.055	0.045	0.23
4053	0.56	0.86	0.32	0.030	0.035	0.22
4063	0.62	0.84	0.32	0.230	0.075	0.23

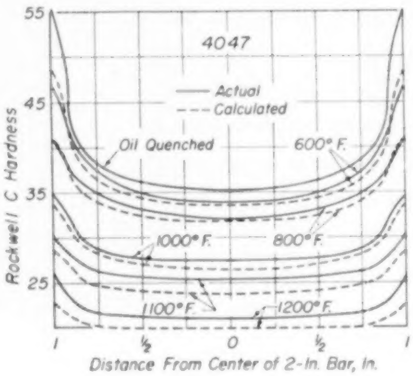


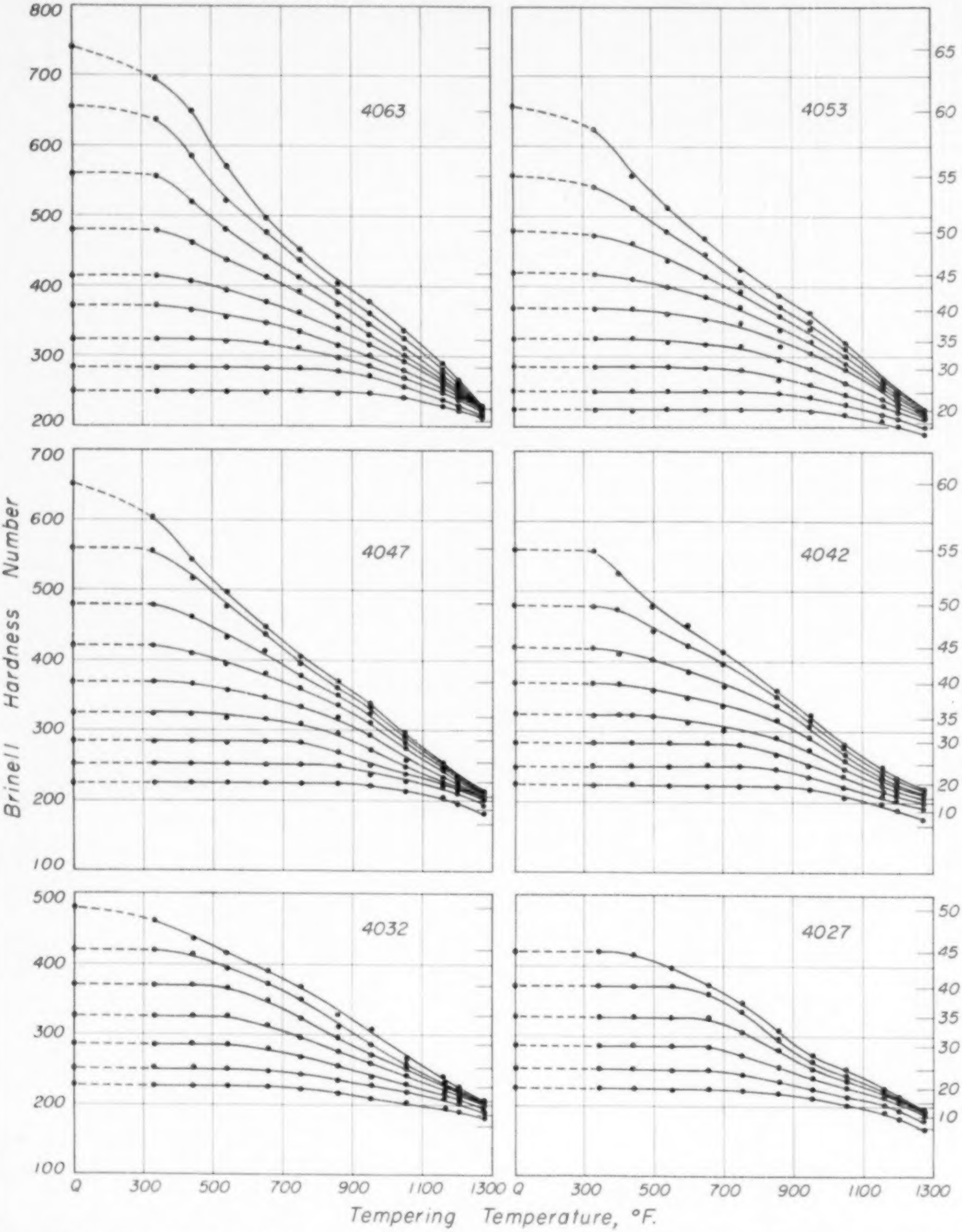
Fig. 2 — Comparison of Actual and Calculated Tempering Curves for 2-In. Rounds

Table II — Effect of Time in Tempering 4063 Steel

Distance from Quenched End, $\frac{1}{16}$ th's	As-Quenched Rockwell C Hardness	Rockwell C Hardness After Tempering at 900° F. for the Indicated Times			
		15 Min.	60 Min.	120 Min.	600 Min.
1	65	44	43	42½	41
4	63	44	43	42½	41
6	59	43	42	41¼	40¼
7	53½	40½	39¼	39¼	38½
8	44¾	37¼	36½	36¼	35½
9	39	35	34½	33¾	33
10	36¼	34¼	33¼	33	31¾
12	34¼	32¾	32	31½	30¾
16	32¾	31¾	30¾	30¼	29¾
24	30¾	31	30¼	30	29
32	30¼	30½	30¼	30	29

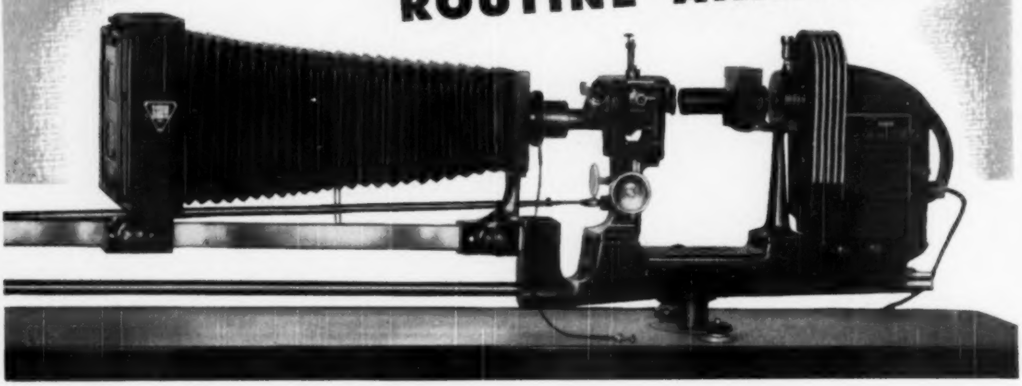
Effect of Tempering Temperature on the Hardness of Carbon-Molybdenum Steels

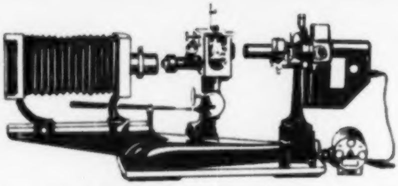
By R. D. Chapman and W. E. Jominy, Chrysler Corp.



NOTES: Molybdenum content was between 0.22 and 0.24% for each steel. Carbon contents were 0.62, 0.56, 0.47, 0.43, 0.31 and 0.27% for 4063, 4053, 4047, 4042, 4032 and 4027 respectively. Duration of tempering, 1 hr.

Designed Especially for SPEED and ACCURACY in ROUTINE ANALYSIS





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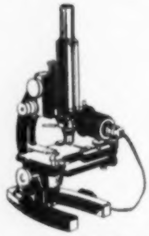

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estimated microscopically.* This provides a direct correlation between structure and hardness for two of the steels whose temperability is reported in this article. Micrographs showing 10 and 50% martensite for the 4047 and 4063 steels are shown in Fig. 4 to 7.

When the microstructural variations shown in Fig. 3 are considered in conjunction with the tempering curves for these steels, it will be evident that martensite, bainite and pearlite soften at different rates, with pearlite giving the least change in hardness at a given tempering temperature. Although martensite shows the greatest drop

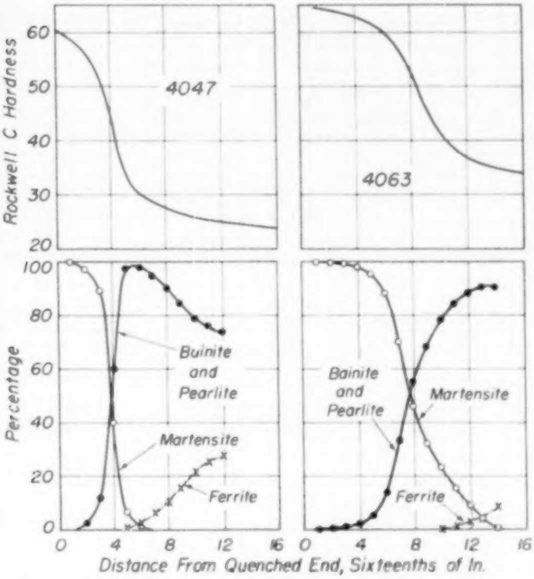


*Fig. 3 — Hardness and Microstructure Along the End Quenched Hardenability Bars of Steels 4047 and 4063**

in hardness at a given temperature, it retains the highest hardness for any treatment. Even at a tempering temperature as high as 1275° F. the tempered martensite is a little harder than tempered pearlite. This difference is, of course, far greater at a temperature of 1000° F. where, for instance, 4063 shows a hardness of Rockwell C-38½ for tempered martensite, compared with C-24½ for tempered pearlite. Figure 8 shows the effect of carbon content in these steels.

*In these specimens, it is difficult to differentiate between bainite and pearlite. Using both the electron microscope (15,000 ×) and optical microscope, we obtained the following results from one particular area, 2 in. from the quenched end of steel 4063: 40% upper bainite, 25% ferrite, 25% fine pearlite, 10% questionable (either pearlite or bainite). The hardness of this structure was Rockwell C-31.

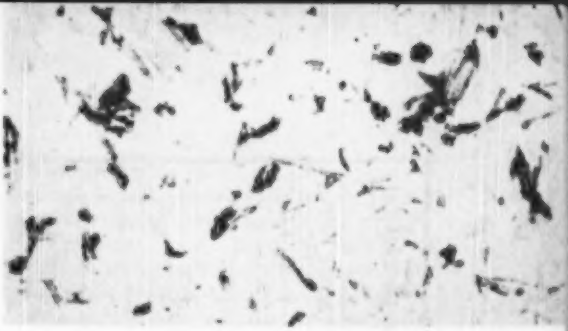


Fig. 4 — 4047, Rockwell C-54, 90% Martensite, 800×

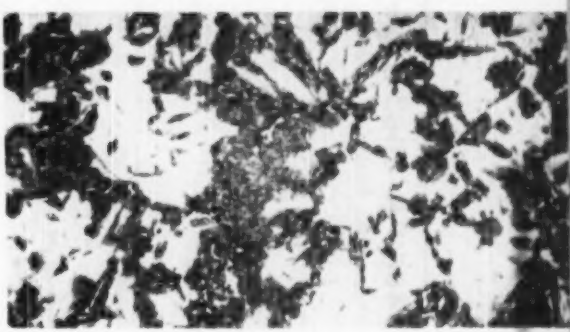


Fig. 5 — 4047, Rockwell C-46, 50% Martensite, 800×

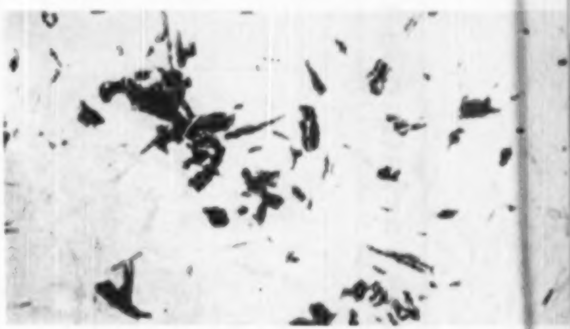


Fig. 6 — 4063, Rockwell C-60, 90% Martensite, 800×

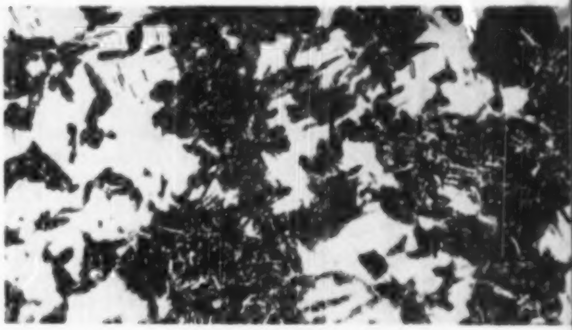


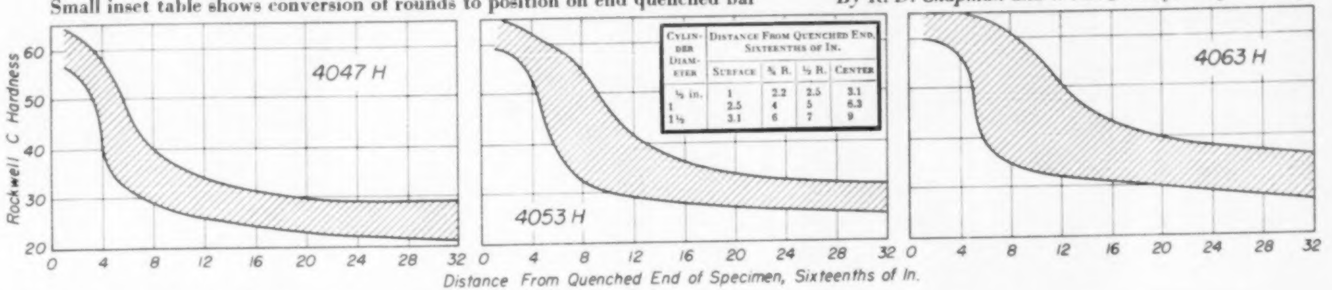
Fig. 7 — 4063, Rockwell C-52, 50% Martensite, 800×

H-Bands & Hardness Variation in 4047, 4053 & 4063 After Tempering

Limits computed from the H-bands and from tempering data on one heat of each steel

By R. D. Chapman and W. E. Jominy, Chrysler Corp.

Small inset table shows conversion of rounds to position on end quenched bar



Cylinder Diameter	Distance From Quenched End, Sixteenths of In. Surface	¾ R.	½ R.	Center
½ in.	1	2.2	2.5	3.1
1	2.5	4	5	6.3
1½	3.1	6	7	9

Table III — Hardness Variations After Tempering

Position in Section	Cylinders ½ In. Diameter As Quenched	Tempered 1 Hr. at (°F.) 600	800	1000	1200	Cylinders 1 In. Diameter As Quenched	Tempered 1 Hr. at (°F.) 600	800	1000	1200	Cylinders 1½ In. Diameter As Quenched	Tempered 1 Hr. at (°F.) 600	800	1000	1200
Steel 4047 H (0.44 to 0.52% C, 0.60 to 0.95% Mn, 0.20 to 0.35% Si, 0.20 to 0.30% Mo)															
Surface (Max.)	64	51	43	35	24	62	50	42.5	34.5	23	61	49.5	42.5	34	23
Surface (Min.)	57	49	41.5	33.5	22.5	54	48	41	33	22.5	51	46	39.5	32	22
¾ Radius (Max.)	62	50	42.5	34.5	23	58	49	42	33.5	22.5	48	44.5	38.5	31.5	21
¾ Radius (Min.)	54	48	41	33	22.5	40	38	35	29	19	32	31.5	30	24.5	17
½ Radius (Max.)	62	50	42.5	34.5	23	54	48	41	33	22.5	42	39.5	36	29.5	20
½ Radius (Min.)	53	47	40.5	32.5	22	34	33.5	32	26	18	30	30	28.5	24	17
Center (Max.)	61	49.5	42.5	34	23	45	42	38	30.5	20	33	32	30.5	25	17
Center (Min.)	51	46	39.5	32	22	31	31	29	24	17	28	28	27.5	23	16.5
Steel 4053 H (0.49 to 0.57% C, 0.70 to 1.05% Mn, 0.20 to 0.35% Si, 0.20 to 0.30% Mo)															
Surface (Max.)	65	54	46	39	28	64	53	46	39	28	63.5	52	46	38.5	28
Surface (Min.)	59	50	43.5	36.5	26	58	49.5	43	36	25.5	57	49	42.5	36	25
¾ Radius (Max.)	64.5	53.5	46	39	28	62	52	45	38	27	59	50	43.5	36.5	26
¾ Radius (Min.)	58.5	50	43.5	36.5	26	53	46	41	35	24	38	37	35	30	21
½ Radius (Max.)	64	53	46	38.5	28	60.5	50	43.5	36.5	26	47	44	39.5	33	22.5
½ Radius (Min.)	58	49.5	43	36	25.5	45	42	38.5	34	23	30	30	28	25	18
Center (Max.)	63.5	52	46	38.5	28	59	50	43.5	36.5	26	42	40	36	32	22
Center (Min.)	57	49	42.5	36	25	37	36	33.5	29.5	21	29	29	28	24.5	18
Steel 4063 H (0.59 to 0.69% C, 0.70 to 1.05% Mn, 0.20 to 0.35% Si, 0.20 to 0.30% Mo)															
Surface (Max.)	65	54	46	39	28	65	54	46	39	28	65	54	46	39	28
Surface (Min.)	60	51.5	44.5	37	27	59	51	44.5	36.5	27	59	51	44.5	36.5	27
¾ Radius (Max.)	65	54	46	39	28	65	54	46	39	28	64	53	46	38.5	28
¾ Radius (Min.)	59.5	51.5	44.5	37	27	57	49.5	43	36	26	39	37.5	34.5	30	23.5
½ Radius (Max.)	65	54	46	39	28	64.5	54	46	39	28	62	52	45	38	27
½ Radius (Min.)	59	51	44.5	36.5	27	50	45.5	40.5	33.5	25.5	36	35.5	33	29	23
Center (Max.)	65	54	46	39	28	63	52.5	46	38.5	28	59	51	44.5	36.5	27
Center (Min.)	59	51	44.5	36.5	27	38	36.5	34	30	25	34	33.5	32	28.5	22

Application of the Data

The tentative H-band specifications published by the A.I.S.I.-S.A.E. joint committee give the minimum and maximum hardnesses which may be expected at any location on the end quenched bar for the steel under consideration. By applying the method of Boegehold (S.A.E. *Transactions*, Vol. 52, 1944, p. 472), the locations in sections of oil quenched round bars corresponding to certain positions on the end quenched hardenability bar can be determined. Then, from these two relationships, values of as-quenched hardness can be ascertained for various locations in round bars of several diameters. Finally, by using the data in this paper the decrease in hardness due to tempering at any temperature can be found. By this procedure Table III, on the preceding page, was constructed.

This table shows the hardness distribution to be expected when cylindrical bars of 4047, 4053 and 4063 steels in sections of ½, 1 and 1½-in. diameter are tempered at the temperatures listed. As soon as H-bands are available for the other steels studied in this paper, similar tables may be developed for them.

From Table III it may be seen, for example, that a 1-in. diameter bar of 4047 steel quenched in still oil and tempered at 600° F. can have a maximum surface hardness of Rockwell C-50 and a minimum core hardness of Rockwell C-31. Of course, if the steel is on the minimum side of the hardenability specification the surface hardness obtainable would be Rockwell C-48, which gives a spread of 17 points from the surface to the center of the bar. Similarly, if this steel were tempered at 1000° F., the surface hardness would be Rockwell C-33 and the center hardness Rockwell C-24, or 9 points from surface to center.

Another point of interest is that at the surface there is very little difference in hardness between steels with a maximum range in hardenability, but at the center, variations are large. Consider a 1-in. diameter part made from 4047 steel, oil quenched and tempered at 800° F. From Table III it is evident that the center hardness may vary from Rockwell C-29 to 38, corresponding to a tensile strength of 138,000 to 176,000 psi. The lower value may be too low if the part is to withstand tensile stresses at the center in service. If the steel is stressed in bending or torsion, the effect of the soft core is minimized, but even for this type of stressing it is usually desirable to have a hardness corresponding to 90% martensite at the ¾-radius position.

It may be seen from the table for 1½-in. diameter 4063 steel tempered at 800° F., that a variation in hardness from Rockwell C-34½ to 46 exists at the ¾-radius position, which gives a spread in tensile strength from 161,000 to 219,000 psi. The differences in hardness or tensile strength do not give the true picture; the actual result will be even more unsatisfactory because the structure having the hardness Rockwell C-34½ will not consist of tempered martensite and will consequently have a lower fatigue limit than might be inferred from hardness number or corresponding tensile strength. The structure where the hardness is C-46 *will* be tempered martensite, which will give a higher fatigue limit than a mixture of martensite and bainite of the same hardness. The same is true of impact. Consequently, if the parts are subjected to fatigue or impact the spread of properties indicated may be more than should be permitted. In the event of parts being subjected to fatigue or impact conditions, a smaller variation in the hardenability band specification would be desired if the section size of the part is as great as 1½ in.

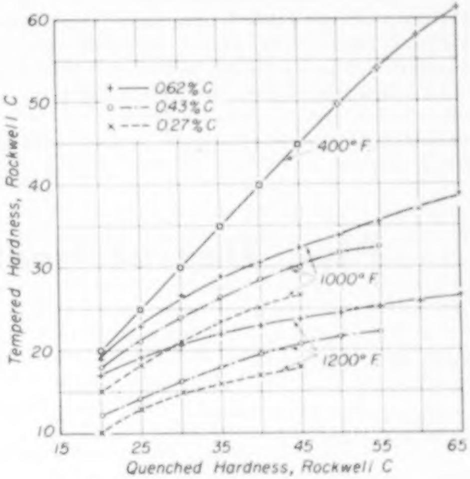


Fig. 8 — Effect of Carbon Content on Tempered Hardness of Carbon-Molybdenum Steels

Table III shows the best hardness control that can be obtained with ideal heat treating conditions, provided the steel is purchased to the H-band specifications. If the temperature varies in the tempering furnace — as it must from practical considerations — this hardness spread is bound to be greater. For example, at 1100° F., if we have a deviation of ±20° F. from the exact temperature of the work to the correct thermocouple temperature, an additional 2 points Rockwell C must be added to the spread shown in the table. It will be

observed that the differences in hardness due to hardenability variations among the steels of the same specification are far greater than those due to a 40° F. difference in tempering temperature. In fact, this hardness difference may be as great as that resulting from a change of 300° F. in the tempering temperature.

Conclusions

1. The reduction in hardness from any as-quenched hardness due to tempering has been determined for six 4000 series steels. The tempering temperatures studied have been from 340 to 1275° F. These data enable the prediction of tempered hardness from any as-quenched hardness.

2. At a given tempering temperature martensite softens more than bainite, and bainite more than pearlite.

3. At the higher tempering temperatures, the difference in hardness between martensite and pearlite becomes increasingly smaller. However, there is a difference of from 5 to 12 points Rockwell C, even at 1275° F.

4. Low-carbon steel with the same as-quenched hardness as high-carbon steel will soften more than the high-carbon steel at temperatures around 800° F. or above. At 400° F. there is no difference between low- and high-carbon steels in this regard.

5. The divergence of tempered hardness due to variations in hardenability permitted by the H-band specifications is far greater than that produced by the differences in tempering temperature that might be expected with good heat treating practice.

Plug Dezincification in Cartridge Brass

By A. L. Simmons
Senior Metallurgist
Government Ammunition Factory
Melbourne, Australia

SEASON CRACKING and dezincification are troubles that have plagued brass articles since a brass button was first made or a brass tube was first used in a hot water system. Naturally these troubles were also the first to be studied when the metalworking art was being transformed into metallurgical technology (not to say science). Yet the diseases are still with us. For example, there was an extensive occurrence at the Australian Government's Ammunition Factory during the war years of plug-type dezincification in cartridge brass.

The type of defect was known locally as "measles", presumably due to the occurrence of a number of reddish spots irregularly distributed over the surface of the brass. The "measle" (if this noun can be used in the singular number) consisted of a copper stain, generally circular and not more than 1/4 in. in diameter, surrounding a small central hole or crater. The hole was sometimes empty but on occasion contained loose spongy deposits of copper, or an inclusion of nonmetallic character, or a metallic inclusion such as a particle of lead or steel. The copper stain sometimes faded away to the edge, but where inclusions were present the stain was normally surrounded by a dark brown area and the copper color was more intense. The photograph shows a typical example enlarged approximately eight diameters.

Most of the trouble was experienced with cartridge cases, yet measles were also found, to a minor extent, in the disks used for making these cases. Measurements of the depths of craters on 15 cartridge cases representing the worst of 200 showed a range of 0.001 to 0.0065 in., with a mean of 0.0027 in. The maximum (0.0065 in.) represented about 20% of the wall thickness.

Very little trouble of this type had been experienced when annealing scale had been removed by vat pickling — only after the vats were replaced with spray pickling machines. For vat pickling a sulphuric acid solution of 1.5 to 2.5% concentration was used at 100 to 140° F., while for spray pickling the concentration was 0.8 to 1.5% and the temperature 85 to 100° F.

After a considerable amount of plant and laboratory experimental work it was concluded that the measles were cases of plug dezincification, and their formation was governed by:

1. The presence of small holes or of metallic

or nonmetallic inclusions as a necessary nucleus.

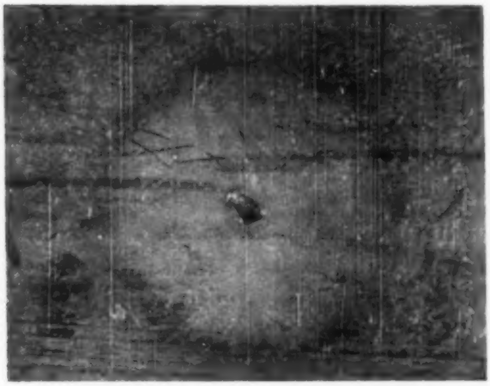
2. Steel inclusions, which had to be larger than about 0.01 in. to cause trouble.

3. Lead inclusions, which appeared to be relatively harmless.

4. Agitation or aeration of the solution would accelerate corrosion, once the latter had started.

The mechanisms of measles formation were considered to be as follows:

In the case of holes (and probably also porous nonmetallic inclusions, or those in which a pocket was left between the brass and the inclusion), corrosion was mostly due to a concentration cell being set up between the solution in the hole and that at the surface of the brass. Within the hole the metal ion concentration would tend to become greater and the dissolved oxygen concentration less than in the solution at the surrounding surface of the brass, because the latter had more chance of replenishment. Hence a potential difference would be set up between the metal in the hole (anodic) and that around the hole (cathodic), and the hole would enlarge or deepen by metal going into solution if the potential difference were great enough. The dissolved metal (copper) would tend to deposit around the hole. The resistance of the electrical circuit would increase with distance from the hole, and a point would be reached at which the product of current times the resistance potential drop brought the effective potential difference below the value necessary for copper deposition; hence the fading out of the copper deposit after a certain distance from the hole.



Typical Dezincified Spot in Cartridge Brass, About Eight Times Natural Size. An epidemic of such spots ("measles") infested cartridge cases after pickling equipment was modernized — spray equipment substituted for vats

Ordinary galvanic corrosion would take place where the inclusions were metallic, the more positive metal dissolving and the less positive metal plating-out around it. This would readily occur with a steel inclusion, and it was found experimentally that the process was under anodic control — that is, the rate of reaction was controlled by the area of anode, and when the latter decreased below a certain small area, polarization was sufficiently great to stop corrosion. Once galvanic corrosion had started, the interface of the two metals would be most severely corroded and a pocket formed, and it is probable that a concentration cell would also be set up at this stage of the phenomenon, thus accelerating the corrosive action and further enlarging the hole.

It must be realized also that solution of steel inclusions and deposition of copper in their place could occur by simple chemical replacement. This may account for the deposits of spongy copper found in some of the holes.

Occasional inclusions of lead were found where there was no indication that corrosion had been influenced thereby. Experimental work showed that the potential difference between lead and cartridge brass was much less than between steel and brass in the pickling solutions used; this, in conjunction with the fact that lead sulphate is relatively insoluble, would explain the reason for lead inclusions being comparatively harmless.

As regards the influence of process (vat pickling versus spray pickling), it would be expected that the effect of agitation would be to cause more rapid corrosion, as the surface polarization products would be washed away and fresh surfaces exposed. Without agitation the corrosion cell would become polarized after a short time and corrosion would stop. Furthermore, aeration, as encountered in spray pickling machines, would tend to make the metal around a hole more cathodic, due to fresh supplies of dissolved oxygen, without much affecting the solution in the hole. Hence the potential difference would be increased and the severity of corrosion accentuated.

This example of dezincification bears out Mars G. Fontana's statements in his excellent article "Dezincification and Erosion-Corrosion" in *Metal Progress* for May 1948: " . . . . . . the plug type seems to favor the low brasses (lower zinc content). More aggressive corrosion conditions — for example, higher temperatures — also favor the plug type of attack, which is related to pitting in that localized attack is involved . . . . . . favorable conditions for this type of attack involve a good electrolyte such as sea water, slightly acid conditions, or the presence of appreciable amounts of oxygen in the liquid handled."

Modern Heat Treating

II—Traditional Operations

By William Adam, Jr.
Vice-President
and Leon B. Rosseau
Assistant Vice-President
Ajax Electric Co., Philadelphia

Prominent among the advantages of salt baths for the heat treatment of steel that are responsible for their widespread use in such traditional operations as heating for quenching is the rapid heating cycle and the ability to operate at maximum permissible temperature which minimizes time at heat. Together with low proportional mass of baskets or fixtures, these factors mean that a small unit, inexpensive as to first cost and floor space, can handle unusually large quantities of work. Surface reactions, whether carburizing or neutral, can be kept under ready control.

In *Metal Progress* last month a brief introduction to the subject of "Modern Heat Treating" reviewed the available salt bath equipment. The principal applications likely to be met in industry will now be examined, first concentrating on what might be called the traditional operations of annealing, quenching and case hardening. In a subsequent article the up-to-date isothermal and cyclic treatments will be considered.

Annealing by means of a salt bath furnace, as differentiated from cyclic annealing, is of limited application. For example, where a full anneal is required to refine the grain of the steel, a *slow* cool from above the upper critical temperature is required. It is not economical to do this in a salt bath because of the high heat capacity of the bath. Practically all of such installations in use are, therefore, for "process anneals", an operation generally

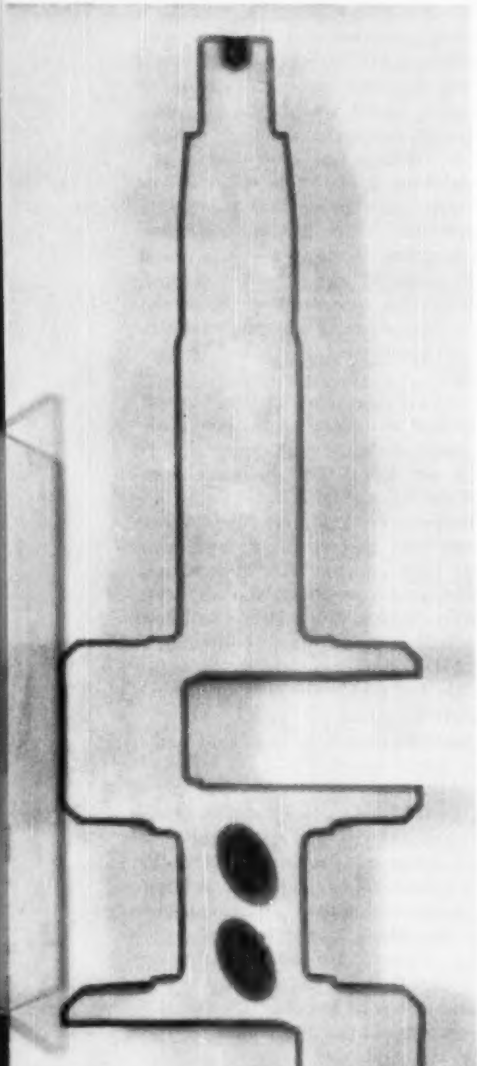


Fig. 3 — Unretouched Macrograph of Cross-Sectioned Carburized Crankshaft. Note uniformity of the 0.040-in. case

carried out below the critical point of steel (in the range of 1250 to 1350° F.) for relieving cold working stresses. The time at heat is short — less than one hour — and the work can then be cooled rapidly in air or water without hardening. The surface of the work is clean and bright. Large production can be secured with a very moderate investment at a competitive cost per ton. For instance, the first cost and floor space are generally from one half to one third that required for bell-type furnaces. Annealing low, medium and high-carbon steel wire or rod in coils is one of the recognized applications.

Stainless steel products and nickel-chromium alloys have also been very successfully annealed. The temperature is from 1550 to 2100° F., the time cycle approximately 30 min., and the work is quenched directly in water. A certain amount of tarnish is produced on the surface but it can be removed by a light acid dip. There again very large production per dollar of investment and square foot of floor space is obtained with low operating costs.

Neutral Hardening

Neutral hardening is a term meaning the hardening of steel without affecting its surface — that is, without oxidizing or scaling it, and without addition or subtraction of carbon. (See Fig. 5,* p. 500). The salt must be "neutral" to the steel in that sense and serve only as a heating medium. It is generally a mixture of chlorides. (Simple rectifying† means are sometimes, but not always, used.) The work is heated in one quarter the time required in a radiantly heated type furnace; thus high production rates are secured from compact equipment.

Large furnaces are common. They are almost invariably equipped with a ceramic pot; interlocking joints are used to key all of the tiles together and thus maintain size and tightness. Neutral hardening furnaces are always equipped with carefully constructed covers since heat losses from a clear bath are of a high order. There are practically no engineering limitations to the sizes which can be built; only the economics of the operation controls the dimensions.

In the heat treater's bag of tricks neutral hardening corresponds to controlled atmosphere heating, and is used for an infinite variety of applications involving carbon steel, alloy steel, die steel, stainless steel, cast irons and steels. The elimination of atmosphere generators, the high capacity of the equipment, and the inherent control of distortion are responsible for the hundreds of installations now in service — one of which is shown in Fig. 4, below.

*Figure numbers are continuous with those in the preceding article.

†"Rectification" is a word which generally means removing undesirable dissolved oxygen or oxides from the bath, either by precipitating them as a sludge (for example, insoluble silicates) or by reducing the oxides (for example, by stirring with a graphite rod).

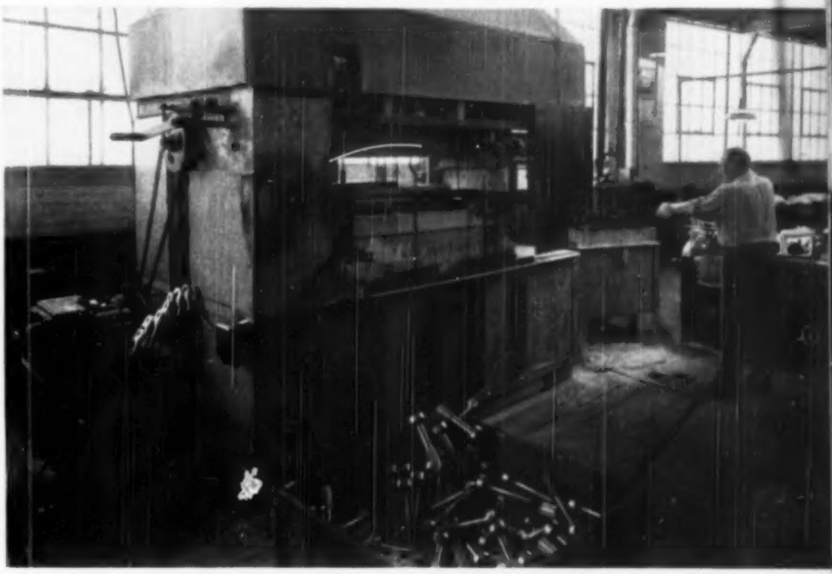


Fig. 4 — Hardening Automotive Spline Shafts in a Neutral Salt Bath Equipped With a Screw-Conveyer Mechanism. Hangers (leaning against side of furnace casing) are hung from arm at left edge of hood and loaded with shafts. Load is swung 90° to fit narrow slot into molten bath along front of furnace. When the load is immersed, the hanger is against screw and gradually moves to right. Heated load is then raised (behind chain heat reflector) and the operator quenches the shafts one by one

High Speed Steel Tools — The hardening of high speed steel tools is the most exacting operation in industry today. We are asked to heat the steel right up to point of incipient fusion (2200 to 2400° F., depending on the analysis), and retain a bright, clean surface on sharp edges without any surface imperfections. The value of a single day's production of highly machined tools may equal the total investment represented by a battery of furnaces. Logically, therefore, superior quality in the finished product is the major requirement; operating cost is secondary. It is highly significant that the majority of quality tool manufacturers are now using salt bath furnaces. Any of these toolsteels, whether the tungsten, the molybdenum or the cobalt type, can be hardened with equal ease and safety, merely by a change in the temperature setting of the furnace. Figure 6 shows results possible from a tungsten type of high speed. Internal stresses in the finished piece are negligible because of the common use of another salt bath for a quench; as a result, cracked tools are a rarity.

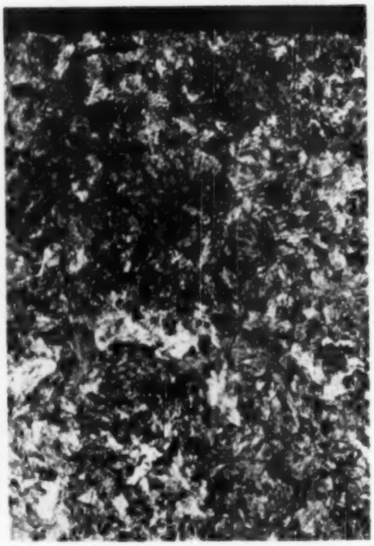
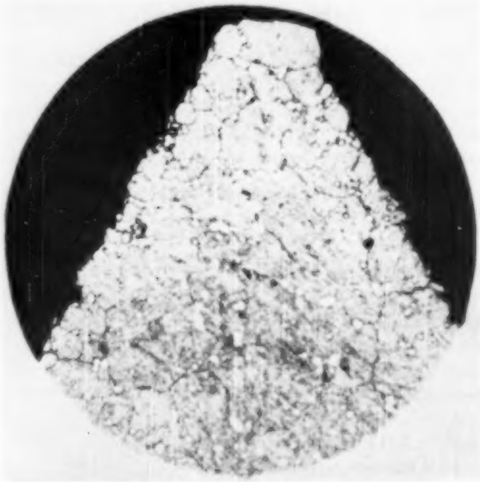


Fig. 5 (Left) — Photomicrograph at 100 Diameters Showing Absence of Scale or Decarburization in Cross-Sectioned S.A.E. 1085 Steel Heated at 1500° F. in a Neutral Salt Bath and Quenched in Oil. (Etched in 2% nital)

Fig. 6 (Below) — Photomicrograph at 500 Diameters Showing Absence of Decarburization in a Section of 18-4-1 High Speed Steel Cutter Heated at 2350° F. and Quenched in Another Salt Bath at 1175° F. (Etched in 4% nital)



The usual equipment consists of a battery of four furnaces (sometimes as many as six) for the following necessary operations:

1. Preheat to 1550 to 1650° F. (one or two furnaces)
2. High heat (2200 to 2400° F.)
3. Salt quench (1100 to 1200° F.)
4. Cool to room temperature
5. One or two draws (1050 to 1100° F.)
6. Wash and rinse

Occasionally the tools may be surface hardened by heating in a cyanide salt at about 1000° F. This operation requires an additional furnace unit.

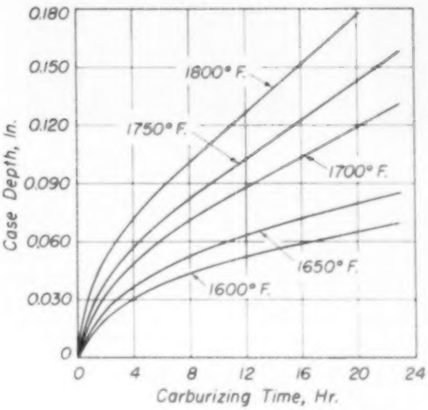
Pots for the preheat and high-heat furnace are generally ceramic, and steel for the quench and draw furnace. Exhaust hoods are usually required over the furnaces and the washing and rinsing tanks. Accurate control of the high-heat furnace is very important since the operating temperature is very close to the melting point of the steel. Radiation-type pyrometer controllers with automatic input control are the standard for this operation.

Carburizing — Liquid carburizing, in principle, is the same as pack carburizing or gas carburizing, since carbon is added to the surface to the required depth. However, sodium cyanide ($NaCN$) is the active ingredient of the bath, and a certain amount of nitrogen (also a hardening element) inevitably enters the steel along with the carbon. Case depths equal to those secured by either pack or gas carburizing can easily be obtained. Somewhat higher temperatures can be employed; 1750° F. is commonly used and some installations operate at 1800°. The time-temperature curves shown in Fig. 7 easily explain the preference for the higher temperature. Notice that the time required is short; for example, a case depth of 0.040 in. is produced in

2 hr. with a bath operating at 1750° F. In fact, the salt bath is the fastest carburizer in use today because the permissible operating temperature is high, because the time required to bring the work to temperature is so short as to be negligible, and because the proportion of weight of work to fixture is so large.

A carburizing bath always operates with a heavy carbonaceous scum on its surface — an efficient heat insulator. The pot is made of welded steel plate and large furnaces are now in operation, some of which are fully mechanized.

Fig. 7 (Below) — Time-Temperature-Penetration Curves for S.A.E. 1020 in a "Deep Case" Carburizing Bath Containing 10% NaCN



One of the most important characteristics of liquid carburizing lies in the uniform case it produces, regardless of how densely the work is loaded or how intricate the surface. (See Fig. 3, p. 498.) Basket loading is common. In any event, the work can be as densely loaded as mechanical reasons permit. This results in a very efficient and adaptable set-up. It is a simple matter to handle simultaneously work in batches, each requiring its characteristic case depth, since it is easy to immerse various charges in the bath for the proper time. There is no cover on the furnace to interfere. Likewise, there is no impairment of efficiency. The only requirement is to keep track of individual charges and to control the time in the bath.

Work can be efficiently quenched directly from the bath since the furnace can be emptied piecemeal. Distortion is of a very low order. This combination of advantages provides a very practical unit and accounts for the constantly increasing popularity of liquid carburizing.

Cyaniding in Salt Baths

Cyaniding is a process for imparting a shallow, file-hard case on the surface of steel in a relatively short time. It is conducted in a bath containing from 15 to 30% of sodium cyanide. The time-temperature penetration curve, Fig. 8, flattens definitely after 60 min. so that 0.010 in. is about the maximum case which can be expected. The effect is due to a combination of nitriding and carburizing which accounts for its extreme hardness.

Cyaniding furnaces are usually equipped with plain welded steel pots which have surprisingly long life. This is attributed to the fact that the steel plate is protected by the scale which forms on the outside surfaces, while the inner surfaces are protected from oxidation by the CO gas generated in the cyanide bath. Good fume exhaust hoods are mandatory, as the sodium carbonate fumes are uncomfortable to the operating personnel. Cyanide is poisonous. All who come in contact with it should be well informed of the dangers; warnings should be conspicuously posted and first-aid equipment on hand.

Batch-type furnaces are most generally used, because they can handle relatively large production in a comparatively small furnace. However, many large, mechanized units are used in the mass production industries.

In general, cyaniding is used to secure a shallow and cheap wear resisting surface of high quality. Such articles as screws, grease fittings, business machine parts, roller chain components, dental burrs, sewing machine parts, shafts, bolts, and hundreds of other items are cyanided. It is also used for the hardening of heavy-duty, quality gears in the automotive field, where the high surface hardness is of great benefit. Cyanide baths are also in general use for reheating carburized work.

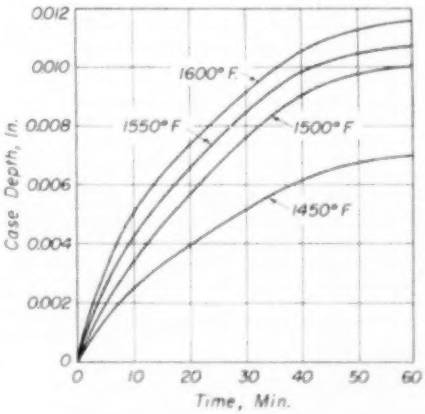


Fig. 8 (Above) — Time-Temperature-Penetration Curves for S.A.E. 1020 in a Salt Bath Containing 30% NaCN

Movements Among Metallurgists

Bruce S. Old

Bruce S. Old has relinquished his duties with the U.S. Atomic Energy Commission, where for some years he has been chief of the metallurgy and materials branch of the research division. He has recently been elected member of the board of directors of Arthur D. Little, Inc., Cambridge, Mass., the well-known firm of consulting chemists and engineers. He will continue to serve the Atomic Energy Commission from time to time as consultant on problems concerning metals and refractories.

Charles M. Kay has recently been appointed division superintendent of steelworks of American Steel & Wire Co.'s south works in Worcester, Mass. He started with the company in 1936 and has most recently been assistant division superintendent of the Worcester steelworks.

Edgar R. Hack received his B.S. from the University of Illinois in February 1950 and is now a sales engineer with Western Brass Mills, East Alton, Ill.

William J. Mead, formerly with the U.S. Army Chemical Corps, has accepted a position with the materials and engineering division of the research and development department, Colgate-Palmolive-Peet Co., Jersey City, N. J.

Robert C. Spinks is now sales engineer for the Electro Alloys Div., American Brake Shoe Co., Elyria, Ohio.

John R. Quinzio, formerly maintenance engineer for the Carborundum Co., is now chief engineer of the Campbell Elevator Co., Buffalo, N. Y.

C. W. Musser

William J. Kroeger

Exceptional Civilian Service Awards and basic U.S. patents have been issued to **William J. Kroeger** and **C. Walton Musser** of Frankford Arsenal for their designs for recoilless rifles. Dr. Kroeger, who is now head of the physics research branch of the Pitman-Dunn Laboratory of Frankford Arsenal, and Mr. Musser, chief of the mechanical design section of the laboratory, formulated a mathematical theory of the operation of the weapon, reduced it to practical terms and had a simple test model firing within six weeks of the commencement of work on the problem. Further experimental work, much of it in the field rather than the laboratory, finally brought about the first 57 mm. recoilless rifle. Recoilless weapons, since they do not require the recoil mechanism and are therefore light in weight, giving the individual foot soldier the fire power of light artillery, were carried by infantrymen in Okinawa and the Pacific isles as well as along the Rhine.

Haynes Stellite Div., Union Carbide and Carbon Corp., announces the appointment of **William B. McFerrin** as executive vice-president and **Robert M. Briney** as vice-president in charge of wrought alloy products. Mr. McFerrin was formerly assistant manager of development, Electro Metallurgical Div., Detroit, and Mr. Briney was manager of the development division, Union Carbide and Carbon Research Laboratories.

K. R. Knoblauch has been named manager of sales of valve products for the industrial division of Minneapolis-Honeywell Regulator Co. Mr. Knoblauch joined the Brown Instruments division of the company in 1924 and has been associated with the industrial division since 1939.

P. C. L. Van Bueren has recently joined the staff of W. S. Rockwell Co., Fairfield, Conn., as coordinator between engineering and production. He was formerly chief engineer for Dempsey Industrial Furnace Corp., Springfield, Mass.

W. D. Hazelton, formerly chief engineer for Electro Alloys Div., American Brake Shoe Co., has joined the Duraloy Co. as sales engineer in Detroit.

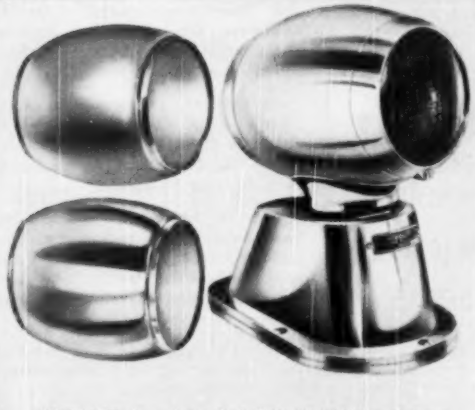
Keith S. James, formerly a heat treater with North American Aviation, Inc., and Douglas Aircraft Co., in Los Angeles, is now doing similar work in Fort Worth, Tex., with Consolidated Aircraft Co.

Dara M. Davar is now at the Inland Steel Co., Indiana Harbor, Ind.

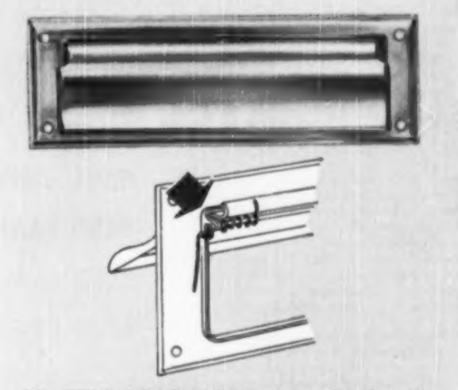
2 MORE EXAMPLES

how manufacturers improved their products . . .
cut production costs with the aid of

REVERE PRODUCTS and SERVICE



UPPER LEFT shows brass shell of the Rev-O-Lite as it comes from the bulging die. Without any extra finishing, which would have been necessary had shell been made of strip and brazed, shell is chrome plated as shown at lower left. At right is the completed assembly of the Rev-O-Lite ready for action on the roofs of all kinds of emergency vehicles such as police patrol cars, ambulances, fire trucks, etc. Chrome finish base is of cast zinc alloy.



THE LETTER BOX PLATE that is not only one of the first to be made from wrought brass but, the Ives Company tells us, has been generally accepted by the trade as the equal of similar items in cast brass. Another example of what can be accomplished when manufacturer and supplier work together.

Line drawing directly above shows detail of construction with Ives exclusive, Weather-Tite interlocking feature.

1. In the development of their Rev-O-Lite, a revolving warning light for emergency vehicles, the Balford Corporation, Jacksonville, Florida, found themselves faced with a production problem regarding the cylindrical shell which contains the lights. The question was; what would be the most efficient and economical way to produce this shell that measures 6" in length and is 4½" in diameter at the ends? Should it be formed from a metal strip and brazed? Could tube be used and bulged in a die? Or, should some other method be employed.

Revere, working with the design engineers of the Balford Corporation, exchanged ideas, weighed the pros and cons of various methods; experimented. They found that by using 70/30 Revere Brass Tube in a light anneal temper, it would take the bulging in the die satisfactorily and at the same time show up well as far as grain size control was concerned. By this method, complicated and costly forming operations and brazing could be eliminated; production speeded and the shell formed without any unsightly seam. Also, no extra hand finishing would be necessary before plating.

2. How can you make a letter box plate out of wrought brass and at the same time have it look like cast brass? This problem of the H. B. Ives Company, New Haven, Conn., came up while the Ives engineers were designing a new type plate employing a new method of interlocking the flap and the frame of the box to insure its being weather-tight.

Casting was ruled out as too costly and impractical to construct. If brass strip was used it had to be heavy enough to simulate cast hardware, yet sufficiently flexible to complete a U bend on a 7" length without fracture or distortion. Also, because the finished plate would in most cases call for a natural brass finish, the stock had to be the right color.

After several consultations with Revere Technical Advisory Service and experiments in their own shop, it was suggested that Revere sheet brass of .062" thickness and of a certain temper be used. That was it! The combination of proper design and heavy gauge metal resulted in a neat but rugged appearance. The wrought construction made it possible to produce a Weather-Tite plate with exclusive interlocking feature without costly machining operations. In addition, finishing costs were reduced to a minimum.

Perhaps one of the many types of Revere Brass or one of the other Revere Metals or Alloys can help you improve *your* product—cut your production costs. Why not tell Revere's Technical Advisory Service about *your* metal problems? Call the Revere Sales Office nearest you today.

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Personals

Francis C. Frary ⊕, director of research for the Aluminum Co. of America, has been awarded the James Douglas Metallurgical Medal for 1950 by the American Institute of Mining and Metallurgical Engineers. The award was granted "for distinguished achievement in science and contribution to society by broadening the field of knowledge in all phases of the aluminum industry and for his notable success in directing a vast research project in this industry".

V. H. Lawrence ⊕, formerly vice-president in charge of plant development and employee and public relations of the Jones & Laughlin Steel Corp., Pittsburgh, was transferred to the newly created position of vice-president in charge of planning and control.

John D. Shaw ⊕, **Walter V. Knopp** ⊕ and **Catherine L. Clark**, formerly of Stevens Institute of Technology, have established S-K-C Research Associates to do experimental research and development work as well as consulting in the field of powder metallurgy.

Following graduation from Case Institute of Technology in January 1950, **John Varga, Jr.,** ⊕ has been employed as an engineering trainee at Lake City Malleable Co., Cleveland.

Edwin R. Szumachowski ⊕, a recent graduate of the Missouri School of Mines and Metallurgy, has become affiliated with Battelle Memorial Institute, Columbus, Ohio.

Clyde B. Netherton ⊕ is now production control officer for the Kadena Air Base maintenance shops on Okinawa. He is also supervisor of the aircraft and aircraft engine conditioning school.

A February 1950 graduate of the University of Wisconsin, **Robert H. Haubrich** ⊕ has joined the American Brass Co., Torrington, Conn., in the sales training program.

Karl F. Schauwecker ⊕, who has been general trade service metallurgist for Carnegie-Illinois Steel Corp. in the Milwaukee district for several years, has been transferred to the Chicago area.

Richard G. Nelson ⊕ has joined the U.S. Bureau of Mines, Albany, Ore., as metallurgist assisting in the development and research of zirconium.

John C. Bronson ⊕ is a mechanical engineer in the design engineering department of the Colorado Fuel & Iron Corp., Pueblo, Colo.

Wm. A. Bauman ⊕, who graduated from Rensselaer Polytechnic Institute in January 1950, is now employed in the magnesium laboratory of the Dow Chemical Co., Midland, Mich.

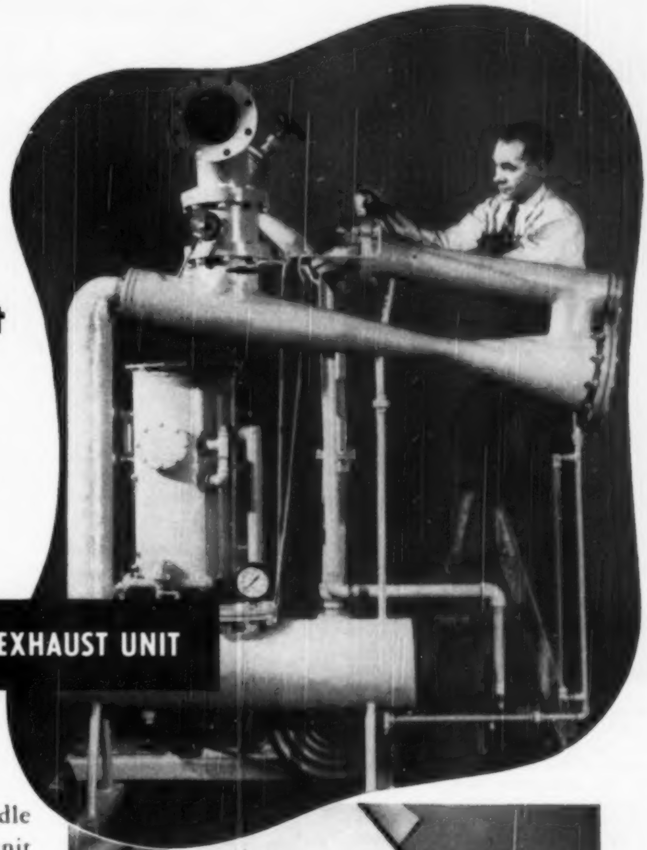
Jack I. Medoff ⊕, formerly assistant technical secretary and assistant editor of the "Welding Handbook", American Welding Society, has joined the McGraw-Hill Publishing Co. as eastern editor of the *Welding Engineer*. His headquarters will be in New York City.

R. B. Dimmick ⊕ has retired as works metallurgist, Butler, Pa., division, Armco Steel Corp., and has been appointed technical consultant of Armco International Corp.

Ronald H. Fillnow ⊕, who received his M.S. degree from the University of Wisconsin in January 1950, has joined the Westinghouse Electric Corp. in its atomic power division as a research metallurgist.

Vernon H. Gallichotte ⊕ is now employed as a mechanical engineer in the forge department of Coulter Steel and Forge Co., Emeryville, Calif.

Another DPi High Vacuum "Packaged" Unit that cuts pumping costs



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Personals

Russell H. Boettger has been promoted to the position of plant metallurgist at Columbia Tool Steel Co., Chicago Heights, Ill.

James E. Murphy, who received his B.S. from the University of Pittsburgh in February 1950, has accepted a position as metallurgist with Carnegie-Illinois Steel's Johnstown, Pa., works.

Everett Wick is now employed as a sales engineer with Metals Protection Co. of Pennsylvania in Pittsburgh.

Lloyd E. Webb has been promoted from chief metallurgist of the Jackson Gear and Forge Div. of Clark Equipment Co. to chief metallurgist of the entire company covering plants located in Buchanan, Battle Creek and Jackson, Mich.

E. A. Baines has recently become production manager of National Cored Forgings Co., New York City.

C. E. Harvey, consulting spectrographer for Applied Research Laboratories, Glendale, Calif., is transferring to that company's Detroit office.

Stanwood Corp., Chicago, announces that **C. P. Critzer**, Case Hardening Service Co., Cleveland, and **R. A. Schmidt**, Pittsburgh, have been appointed its representatives in their respective territories.

Van H. Leichliter has been appointed assistant vice-president of operations of the American Steel & Wire Co. Mr. Leichliter has been with the company since 1930 and has been superintendent of the Worcester south works since 1945.

Pennsylvania Salt Mfg. Co. announces that **J. Ralph Macon** has been appointed engineer in the market research division. He was formerly with Du Pont's electrochemical department.

Following graduation from Case Institute of Technology in January 1950, **D. S. Chambers** has been employed by Republic Steel Corp. at the Central Alloy District, Massillon, Ohio, as a metallurgical observer.

G. L. Garwood, who for the past three years has been working in the test division of the engineering department of Phillips Petroleum Co., has been appointed representative of the company in Odessa, Tex.

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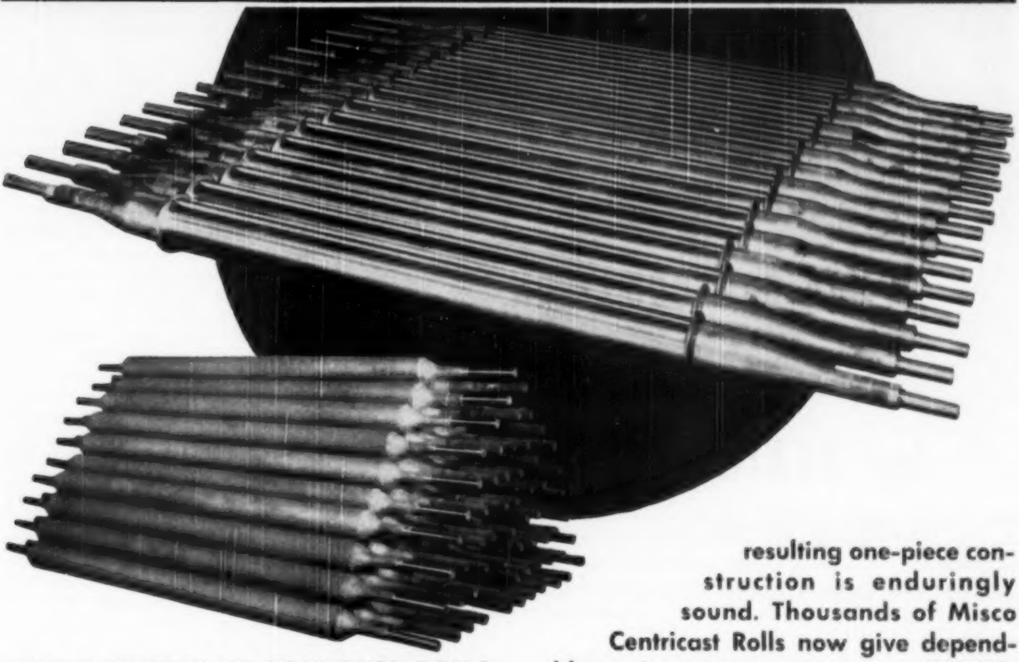

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German Ferrous Metal Industry*

THIS British publication summarizes the information obtained by various British and American investigating agencies after the war and includes items of specific interest from unpublished reports in the files of the British Board of Trade. A list of the documents consulted follows each section of the original report. Tonnage figures cited are metric (2204 lb.).

Raw Materials

The general impression gained from a review of German efforts during the war years in the technology of raw materials and blast furnace operation is one of metallurgical activity devoted largely to the problems encountered in utilization of low-grade ores, and to the development of schemes for meeting the shortages of certain critical materials. Some of the processes developed exhibit considerable metallurgical ingenuity but economic factors obviously were disregarded in the interest of expediency.

Coke produced from Ruhr coals was of good quality both chemically and physically. In order to improve the coking quality of Upper Silesian coals used at Watenstedt (Hermann Goering Works) 3 to 5% of coal tar was added to the mix. The coke works at this plant included one battery of six ovens used for experimental work. Coke ovens usually were heated with either blast furnace or producer gas; the by-product gas was passed through a cleaning plant to extract the sulphur and then supplied to the Ruhr grid.

Limestone supplies are abundant, of high quality and located conveniently to the steel plants. The proportion of burned lime used is high because of the requirements of the Thomas converters. Almost 50% of the shipments by one of the large limestone companies is in the form of burned lime.

The second World War imposed

(Continued on p. 510)

*Abstract from "The Ferrous Metal Industry in Germany During the Period 1939-1945," by George Patchin and Ernest Brewin, Over-all Report No. 15 of the British Intelligence Objectives Subcommittee, obtainable from British Information Services, 30 Rockefeller Plaza, New York City 20. ($1.15.)

German Steel

(Continued from p. 508)

drastic changes on the German steelmaking economy in the quality of the ores available. In 1938 the consumption of iron ore was 32,400,000 tons, including 65% foreign ores, which accounted for 80 to 85% of the total iron content. During the war the industry was compelled to utilize increasing quantities of domestic ores, most of which were very low in iron and contained excessive silica, for example the Salzgitter deposits for which a typical composite analysis reported was 30.50% Fe, 0.15% Mn, 0.5% P, 25.2% SiO_2, 9.4% Al_2O_3, 4.5% CaO, 2.0% MgO. The Hermann Goering Works was built to operate largely from these ores.

A variety of beneficiation schemes were employed for concentrating the low-grade ores for blast furnace use. Crushing and screening, and wet concentration methods, were used to produce concentrates for sintering. Gas-fired rotary kilns (Lurgi) were constructed to convert Fe_2O_3 in the ore to Fe_3O_4 for subsequent magnetic separation. The resultant concentrates did not exceed about 40% Fe and the iron to silica ratio was about 1.7. The cost of enriching the ore even to this relatively low iron content must have been excessive and could have been tolerated only under the abnormal conditions existing in Germany.

The Krupp-Renn units for direct reduction operated at Watenstedt were said to produce pellets *(Luppen)* containing 92 to 95% Fe; however, there were apparently serious operating problems with the kilns and it is questionable whether the process could be considered a success metallurgically.

Sintering plants were of high capacity and modern design. The Hermann Goering Works produced 10,000 tons per day and the investigators reported the product of excellent quality, even though low in iron content. Limestone additions were reported advantageous, provided the material was in a fine state of subdivision. The machines were long and operated at low speed so that no water was required to cool the sinter. The raw materials were carefully graded and screened.

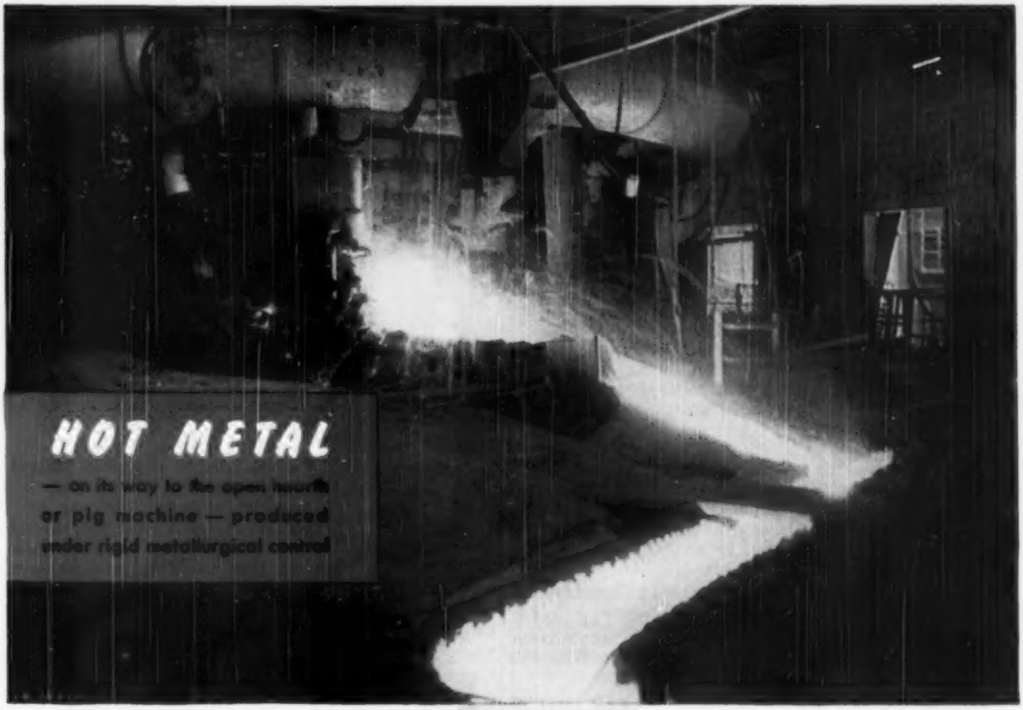
Blast Furnaces

Blast Furnace Equipment — The only important tendency in furnace construction appears to be a trend toward the typical American design in which a heavy shell is supported directly on columns and skip-charged, in contradistinction to the older German units, which are built with a separate steel structure from the ground up supporting the shell, top structure and overhead charging equipment.

Carbon hearths are used extensively and the recent tendency is to employ carbon materials up to the mantle. The hearths are laid up with great care to obtain minimum joint thickness. Experimentally an attempt has been made to produce a carbon lining by ramming a coke-tar mixture to give a monolithic structure, and one furnace so constructed was reported to have produced a million tons of pig iron. Iron runners were sometimes made of carbon block, swabbed with a clay slurry for protection.

Tuyeres of aluminum and of iron were tried because of the copper shortage but were reported

(Continued on p. 512)



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WISCONSIN STEEL

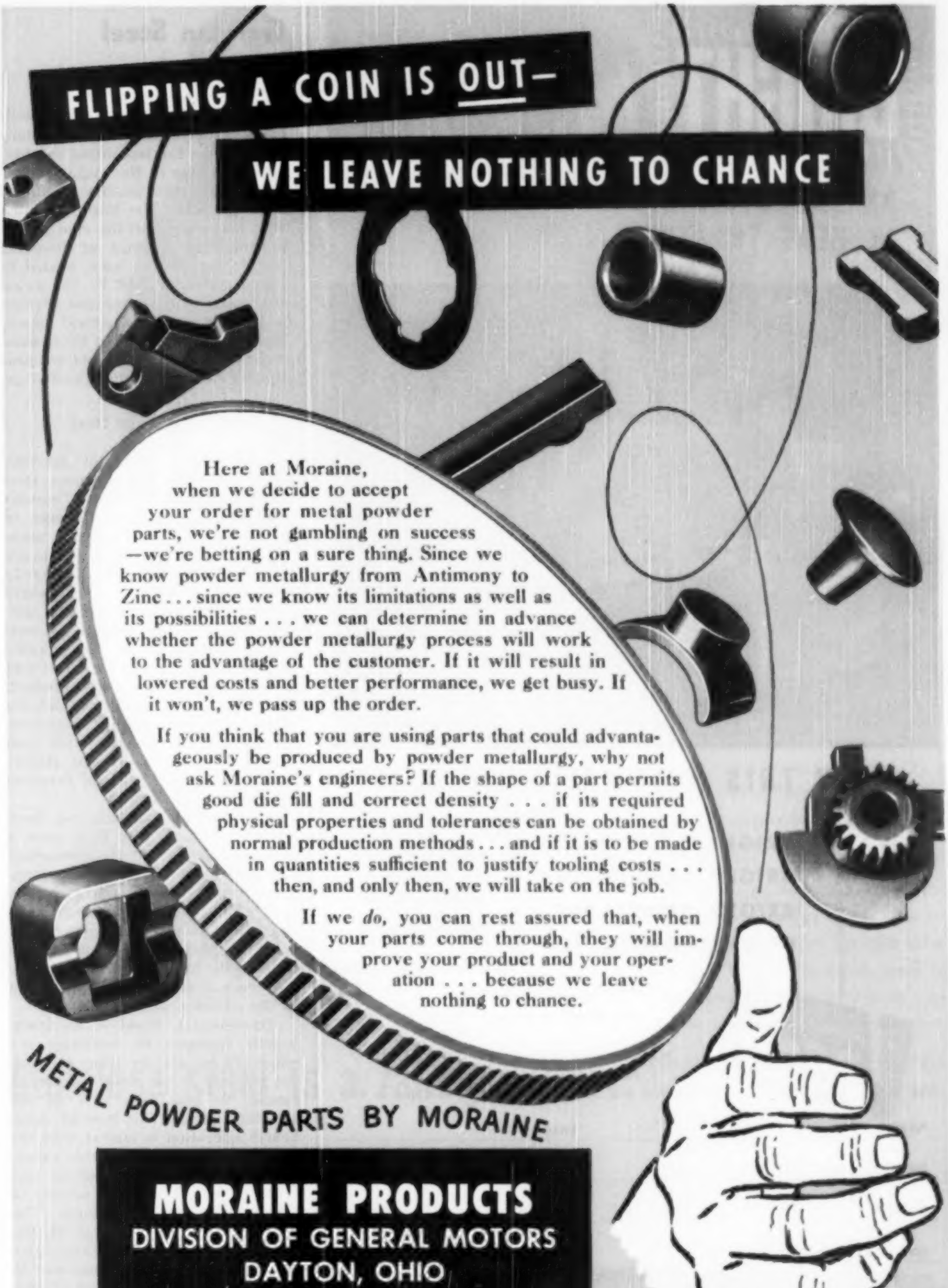
German Steel

(Starts on p. 508)

unsatisfactory. An unusual blowing engine — a Brown-Boveri gas turbine designed to operate on preheated blast furnace gas and air — was under construction at Watenstedt at the end of hostilities but has not yet been operated on a blast furnace. Construction of a full-scale oxygen plant was begun at Gutehoffnungshuette at Oberhausen but has not yet been completed. It is planned to enrich the blast with 75% oxygen introduced just above the tuyere connections. The blast will carry 26 to 30% oxygen and will be heated to between 1470 and 1650° F.

Blast Furnace Operation — The German furnace operators achieved some success in maintaining tonnage levels during the war years but at excessive cost and by the application of metallurgical expedients that would be intolerable to the American operator who is accustomed to high-grade raw materials. A few figures may be of interest. At Hamborn a prewar slag weight of 450 to 500 kg. per ton (900 to 1000 lb. per net ton) increased with low-grade ores to 1200 to 1400 kg. per ton (2400 to 2800 lb. per net ton). Slag basicity in Ruhr plants decreased from a CaO/SiO_2 ratio of 1.2 with Swedish ore to as low as 0.6 to 0.9 with German ores. Concurrently, coke consumption was high, ordinarily around 1200 kg. per ton (2400 lb. per net ton). Reduction in tonnage is indicated by figures cited for the blast furnace plant at Rheinhausen where iron production for the period 1938-1939 totaled 1,525,720 tons; for 1942-1943, 1,153,525 tons.

Ferro-Alloys — Because of the critical shortage of high-grade manganese ores the production of high-grade (80%) ferromanganese was greatly curtailed. Monthly production of blast furnace ferromanganese was 7500 tons containing 30 to 60% Mn and 3400 tons over 60% Mn. In 1944 the monthly output of spiegel was 34,000 tons of 6 to 14% Mn alloy and 2000 tons of 14 to 30% Mn content. The problems of the steelworks operator in meeting specifications with these substandard analyses are obvious. Small-scale attempts were made to dephosphorize low-grade ferromanganese (2.6% P) with magnesium and it was claimed that more than 90% of the phosphorus could be removed at temperatures of 1650° F. or higher. *(Continued on p. 514)*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German Steel

(Starts on p. 508)

Special Processes — Titangesellschaft experimented with a rotary kiln process for separating the titanium and iron in Norwegian ilmenite, intending to produce pigments from the slag. The kiln was lined with magnesite and the charge was a briquetted mixture of ilmenite, NaOH, and coal or coke, heated to a temperature of 2550° F. The lining was coated with magnesium titanate to protect it from chemical attack. The process was said to show some promise of success but had not progressed beyond the pilot plant stage.

Production of Steel

Converters — In 1943 approximately 44% of the German steel production was in basic (Thomas) converters. The huge tonnages of steel required for ordnance made necessary the application of Thomas steel for products that previously had been confined to openhearth grades. The nitrogen content particularly was the subject of metallurgical study, and considerable success was achieved in improving the quality of the converter product. The status of the bessemer process in Germany and elsewhere has been discussed in detail in British Iron and Steel Institute Special Report No. 42, abstracted in *Metal Progress* for December 1949.

Converter slags produced from vanadium-bearing pig iron were a principal source of ferrovanadium in Germany during the war. Manganese-rich slags were likewise recovered by converting spiegeleisen, although this scheme involved both operating and metallurgical difficulties. Both techniques were costly and were dictated by the exigencies of the military situation.

Openhearth Steel — The openhearth furnaces in Germany are employed largely for scrap melting, the pig iron or hot metal amounting usually to less than 25% of the metallic charge. This type of openhearth operation is logical with the high proportion of converter capacity operated in the industry, and renders the metallurgical control of the process relatively simple. The basic openhearth process in the United States has evidently progressed beyond German practice in utilization of a wide range of raw materials and in metallurgical control of operations.

(Continued on p. 516)

German Steel

(Starts on p. 508)

Basic roofs appear to be well-established on the smaller stationary furnaces. Suspended ribbed construction is employed, with adjustable spring-loaded skewbacks. Roof life with Radex brick was claimed to be 1000 to 1400 heats compared with 400 for silica brick. Bottoms were put in with dolomite in most furnaces.

Electric Furnaces — Electric furnaces in Germany make extensive use of converter-blown metal in the charge. During the war alloy steels were made by ladle mixing of electric steel with openhearth steel or soft-blown Thomas metal. The product so made presumably met quality requirements although control problems were doubtless encountered.

Ingots — Bottom casting is used in many openhearth and electric steel plants. In casting heavy forging ingots, over 70 tons, some plants turn the mold slowly on a turntable during teeming, although it is not clear what metallurgical advantage results from this practice.

Continuous casting of steel is still in the experimental stage; nonferrous metals are said to be handled successfully.

Mechanical Treatment

In the manufacture of heavy forgings, practice was orthodox and no advances of outstanding importance were encountered.

The production of railway axles, wheels and tires apparently has changed very little in recent years. One plant had a plan for making solid wheels from a bimetallic ingot to give a tread of harder metal than the center, although there is no indication that such a product was ever actually tried.

Drop forging practice was modern and production capacity high. Die steel compositions used in one specialty plant were:

	Ordinary Dies	Special Dies
Carbon	0.50%	0.50%
Nickel	1.60	1.50
Chromium	0.55	0.90
Molybdenum	0.10	0.50

Cartridge cases for a wide variety of ammunition were drawn from openhearth steel. Stock was annealed, bonderized, blanked and drawn. It was claimed that the bonderizing treatment served not

(Continued on p. 518)

German Steel

(Starts on p. 508)

only as a lubricant but also as a preparation for the surface to carry ordinary lubricants.

Rolling Mills — The newer plants such as the one at Watenstedt are equipped with modern blooming and bar mills designed for high-tonnage output, and from the descriptions given would compare with installations in typical American integrated plants. The Sack continuous billet mills at Watenstedt have alternating horizontal and vertical stands in order to eliminate the need for twisting guides. The pinions for the vertical stands are located overhead and are hollow, with the universal joints located within the body of the pinion. All German blooming mills were equipped with fabric bearings, usually water lubricated. These were installed originally because of the shortage of bronze but are said to be accepted on merit now.

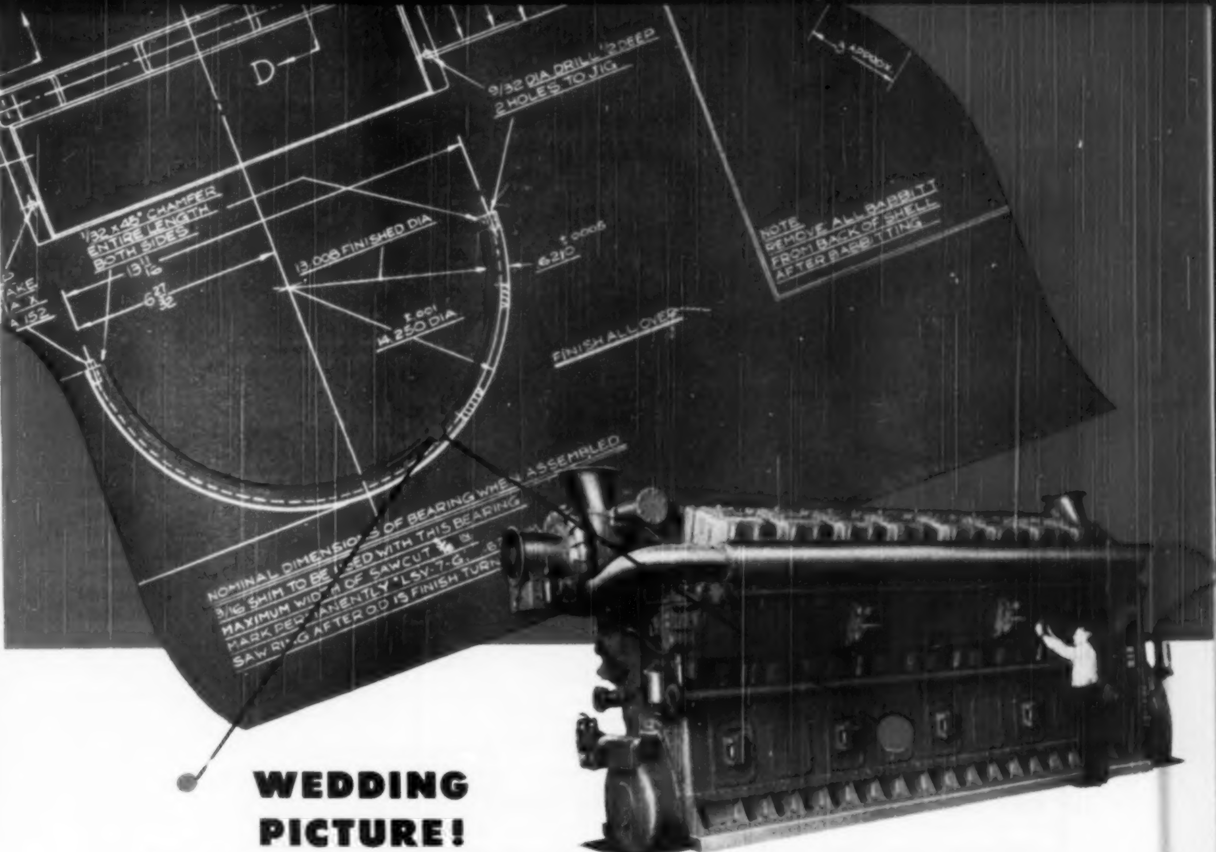
German practice in the production of flat rolled products is outmoded in comparison with American technology. The only wide hot strip mill in Germany was the 1280-mm. (51-in.) installation at Dinslaken and there is no indication that any plates were rolled on this mill. Plate production was largely from 2-high or 3-high mills, common grades being rolled direct from slab ingots. Krupp was the sole producer of armor plate for the German Navy and was a large producer for the Army.

Rod and wire mill practice in Germany had not changed appreciably from prewar years. The newest rod mill in the Hermann Goering Works had never operated. Experiments were conducted with titanium carbide as a substitute for tungsten carbide in dies, with results reported promising.

Tin-plate production was much restricted by the severe shortage of tin; however, some new equipment was installed for electrolytic tin-plate. Much effort was directed toward the development of a lacquered sheet that could be substituted for tin-plate in the manufacture of cans.

In the production of seamless tubes there was little technical development during the war years. Most seamless tubes are still made by the Pilger process, which has been largely abandoned in the United States. Push benches con-

(Continued on p. 520)



WEDDING PICTURE!

You're looking at the blueprint of an important marriage . . . a "marriage of metals"—cast iron and babbitt, a union once considered impossible.

But The Cooper-Bessemer Corporation pioneered the use of centrifugally cast iron bearing shells and effected that marriage through a special process that, for the first time, permitted the tinning and bonding of babbitt to cast iron.

We helped arrange that wedding, too. We supplied the stock in the "as cast" condition in lengths up to 10 feet from which those bearing shells were machined.

Was this new and unusual union successful? Listen to what one well-known authority, T. E. Eagan, Chief Metallurgist of The Cooper-Bessemer Corporation, has to say. Mr. Eagan writes: "We have found that centrifugally-cast iron makes the best bearing back material."

As a fabricator or builder, your problems involving tubular parts may be of a different nature, but whatever they are, we'd like to help you solve them.

We'd like to prove to you . . . as we have to others . . . that centrifugally-cast iron, steel and stainless steel can give you peak quality at a competitive price. Write today and outline your problem. Let's "team up" and see if we can't come up with the answer.

IRON STANDS UP . . . AT LESS COST!

This Cooper-Bessemer Type LSV 16 cylinder Gas-Diesel engine, which is equipped with centrifugally-cast iron bearing shells, is rated at 3400 H.P. at 327 r.p.m. The use of permanent metal molds in the spinning operation, combined with a special mold coating process developed by U. S. Pipe and Foundry Company, produces the tight, dense grain structure required for these bearing shells.

TYPES OF METAL CAST

Stainless Steel—all AISI Types, plus special heat and corrosion resistant analyses.

Alloy Steel—all grades.

Carbon Steel—all grades.

Grey and Alloy Iron—all standard and special analyses, including Ni-Hard and Ni-Resist.

Dual Metal—Grey or alloy iron inside steel; grey iron inside chilled iron, tool steel, or Ni-Hard; iron or steel inside stainless; and many other metallurgically bonded two-metal centrifugally cast combinations.

SIZE RANGE

Outside Diameters—2½" through 30". Wall Thickness—¼" to 4". Lengths—Up to 10'.

U. S. PIPE AND FOUNDRY CO.

SPECIAL PRODUCTS DIVISION BURLINGTON, NEW JERSEY

AMERICA'S LARGEST PRODUCERS OF CENTRIFUGALLY CAST FERROUS METAL PRODUCTS IN TUBULAR FORM

German Steel

(Starts on p. 508)

tinue in use but mostly for the production of hollow shapes to be finished by various combinations of hot rolling and cold reduction. This procedure is advantageous in the production of specialties such as high-carbon steel for ball bearing races, and stainless grades.

The Mannesmann Works employed extrusion for the production of hollow shapes for cold drawing. The tube wall tolerance required in extrusion is stated to be ±12½%. Impact extrusion, in which the sudden application of load to a confined volume of metal produces a shell in a single operation, reportedly had been used in the production of mild steel tubes. Extrusion temperatures for various steels and the compositions of dies and mandrels are given in detail.

This section of the report is concluded with brief notes on the production of ball and roller bearings and the manufacture of springs.

SIMON FEIGENBAUM

Foundry Practice

Postwar studies by various technical teams have given a rather complete picture of the state of German foundry development at the end of the second World War. Production of iron castings in Germany decreased during the war by about 30% but steel castings production increased considerably during the same period. Similar trends were experienced in this country during the war although in the later stage the demand for iron castings was on the increase. A part of the increased demand for steel castings for armament was due to the limitation of forging equipment.

Melting for iron castings was largely by cupola except that reverberatory furnaces were preferred in the foundries making cast-iron rolls. Basic practice was adopted almost exclusively for steel produced in openhearth and electric furnaces. In this country acid practice is more often used for electric melting steel for castings. Most German steel foundries are integrated with comprehensive steel works.

Natural molding sands are used extensively in Germany for iron castings. Steel castings are made in synthetic silica sand mixes, as

(Continued on p. 526)

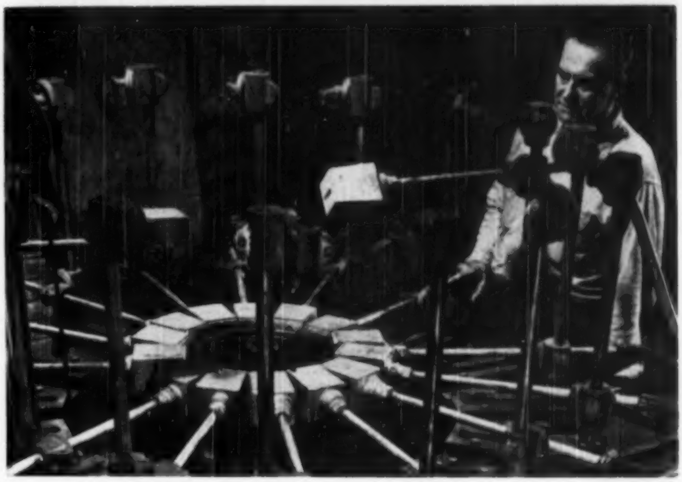
ENGINEERING DIGEST OF NEW PRODUCTS

ROTARY FLAME HARDENER: The development of a machine, designed on a new principle, for flame hardening gears, cams and wheels in all dimensions up to 36 in., has been announced by the Lakeside Steel Improvement Co.

Named the Lakeside Radial Rotary Flame Hardener, the machine consists of a series of patented burners directed on the piece which is mounted on a motor-driven spindle. The work spins at a predetermined rate of speed as it heats, and as soon as the proper temperature is reached, the hydraulic mechanism submerges the work in a tank of water and oil while it is in a spinning motion.

The special, patented burners fit the contour of the gears, cams or wheels and it is possible to increase or decrease the number of burners directed on the piece.

The time of heating and quenching depends entirely on the size. The present machine accommodates work up to 36 in. in diameter with a 4 to 5-in. face.



For further information circle No. 262 on literature request card on p. 524B

STEELSORTER: First commercial production of the Steelsorter, developed by the Jones & Laughlin research department, is announced by the Fisher Scientific Co.

This instrument separates semi-finished and finished steel products that have become mixed. It differentiates between all types of carbon steel by responding to magnetic differences in the metals, regardless of whether the differences are chemical, physical or metallurgical in nature.

Today, steels are "tailor-made" with a different chemical composition for almost every application. Elaborate systems to minimize mixing of steels have been effectively used in mills for many years. Despite continual efforts of the steel manufacturers, jobbers, warehouse men and consumers, steel of identical appearance and diameter but of different chemical composition occasionally becomes mixed. The problem of occasionally mixed grades of steel prompted Jones & Laughlin metallurgists to develop a quick, inexpensive method of sorting out various types.

Particularly designed for use with normal mill stock such as rods and bars as well as with fabricated parts, the Steelsorter is fast and easy to operate and is sensitive to minute differences in the steel. One man using the Steelsorter can separate several hundred small samples per hour and a proportional number of large samples per day.

A further advantage is that the Steelsorter is portable and can be used anywhere that line voltage is available. It is completely nondestructive. The instrument does not mar the surface nor disturb the physical properties of the steel when it is used with highly finished products.

Its versatility is illustrated by the variety of steel shapes and sizes it can separate. It separates round bars, flat bars, hexagonal bars or tubes equally well. In one operation the Steelsorter was used on over 154,000 pounds of 3.66-in. I. D. tubes and made it possible to remove quickly the 200 pounds that were rejected.

The magnetic properties of steel are affected by the composition of the alloy, the compression or tension strains due to cold work or rapid quench, grain size, the size of the specimen, heat treatment and aging. These factors influence the permeability, the hysteresis and eddy current losses in the steel. The Steelsorter is sensitive to changes in all three of these factors.

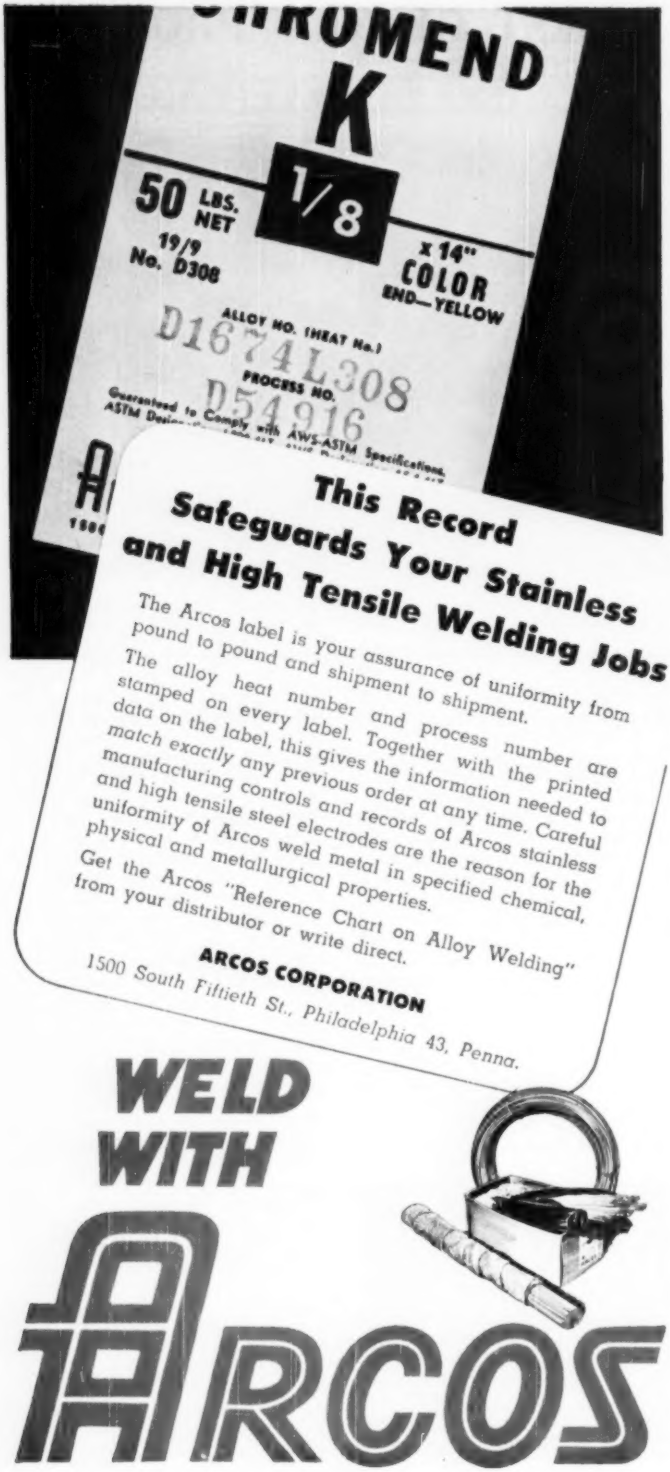
So simple to operate is the Steelsorter that untrained operators can use it to make separations once the instrument is adjusted. The sample is inserted through the opening in the test unit, the button on the top of the unit depressed, and the dial read.

Not only can the instrument be used to differentiate between two pieces of dissimilar steel, but in most cases can also separate batches of mixed steel into groups and show the boundaries of each group.

The Steelsorter is equipped with five separate testpieces, each of a different size. This is necessary because the nearer the diameter of the specimen is to that of the unit, the more efficient the instrument. These sizes have cylindrical openings with diameters of ½, 2, 4, 6, and 9½ in.

The instrument operates from a 110 volt, 50-60 cycle a.c. The control unit of the Steelsorter costs $295, without testpiece units. Extra 12-ft. cables cost $11.50. The prices for individual testpiece units are: ½ in., $85; 2 in., $95; 4 in., $115; 6 in., $125; and 9½ in., $175.

For further information circle No. 263 on literature request card on p. 524B

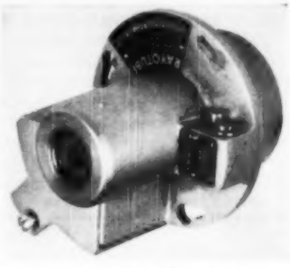


NEW PRODUCTS

RAYOTUBE: Manufactured by Leeds & Northrup Company this new Rayotube features quick sighting and stability in drafts and hot spots.

Built to work with all Micromax and Speedomax Rayotube instruments, present users of Rayotubes, as well as future ones, will find this advanced design detector unusually easy to apply, especially to such equipment as slab furnaces, soaking pits, openhearths, ceramic kilns . . . wherever operating conditions are severe.

Quick-sighting optical system lets user select desired target easily, and then check the sharply-defined area which the Rayotube sees. Increased



sharpness is also of benefit when radiation comes from end of a closed tube.

Hermetically-sealed construction at lens, window, and leadwires keeps out dust and gases. New design guards inherent accuracy and stability, even with high or rapidly changing Rayotube housing temperatures.

Purposely designed for easy, low-cost replacement, the new Rayotube fits all existing Rayotube mountings. This unit requires no protection against high ambient temperature unless its housing temperature exceeds the very high figure of 350° F. Below that point, any previously installed water- or air-cooling can simply be turned off or disconnected.

For further information circle No. 264 on literature request card on p. 524B

TIN DEPLATER: The inexpensive, time-saving process for accurate determination of the weight of tin coating on tin-plate, developed by the research department of Continental Can Co., has recently been made available, license-free, to the entire industry.

Called the Bendix Deplater, after its originator, G. H. Bendix of Continental Can Co., the process involves the removal of tin from tin-plate by electrolytic deplating, followed by titration of the resultant stannous

(Continued on p. 524)

NEW PRODUCTS

(Continued from p. 522)

tin-bearing solution to give accurate measurement of the tin deposit on any given sample of tin-plate.

The entire Bendix deplating process takes only a few minutes and is equally adaptable for quality control of tin-plate made by both the hot dip and electrodeposition methods.

For further information circle No. 265 on literature request card on p. 524B

SMALL HIGH-SPEED DIE CASTING MACHINE: A new 1 lb. capacity zinc-alloy high speed die-casting machine, Model M55 A/HF-1P, is available through DCMT Die Casting Machine Corp.

This die caster utilizes the new principle of fast chill and high cycling speed on low-cost, small, single-impression dies. Direct valving "explodes" air into the cylinder. This causes supersonic piston speed which "shoots" hot molten metal into the cavities before it has a chance to cool off, permitting a small water-cooled sprue which solidifies instantly, resulting in a high speed cycle.

An average production of 500 to 700 shots per hour can be maintained with die sizes up to 6 x 9 in. Floor space measures only 24 x 12 in., weight 470 lbs.

For further information circle No. 266 on literature request card on p. 524B

ALUMINUM ELECTRODE: A new welding electrode for aluminum and aluminum alloys — EUTECTRODE 2101 — is announced by the Eutectic Welding Alloys Corp.

According to the company, this electrode "handles" almost as easily as a mild-steel electrode. Stop-and-start welding presents no difficulties. The weld puddle is visible at all times, because there is no blinding smoke to screen the work. No troublesome fumes or spatter. A smoother, denser weld is the result.

EUTECTRODE 2101 operates at low amperages, as much as 30% less than the amperage required for conventional rods. The low amperage avoids danger of stress and damage to thinner parts. Ideal for reclamation of new castings and repair on old ones.

The new rod has a tensile strength of 34,000 psi. It is available in ⅛-in. and $\frac{3}{32}$-in. sizes.

For further information circle No. 267 on literature request card on p. 524B

268. Abrasive Wear
Six-page bulletin, "How to Reduce Abrasive Wear with Thermalloy HC-250", describes the physical properties of the thermalloy HC-250 and lists the many uses and advantages of this exceptionally abrasive-resistant metal. *Electro Alloys Div.*

269. Air Mixers
New bulletins illustrate and describe the complete line of McKee air-gas proportional mixers for all industrial heat applications. *Eclipse Fuel Engineering Co.*

270. Alloy Castings
New 1950 Reference Chart contains comprehensive analysis of stainless, corrosion and heat-resistant alloy castings. Gives Cooper alloy type numbers along with comparative designations of AISI, SAE, ASTM, etc. In addition, lists properties of alloys at room temperature and high temperatures and discusses their applications. *Cooper Alloy Foundry Co.*

271. Alloy Handbook
New pocket-size Alloy Handbook. It's a mine of nonferrous alloy information — and it's yours for the asking. *Riverside Metal Co.*

272. Alloy, Welding
Handy "Reference Chart on Alloy Welding" provides a safeguard for your stainless and high tensile welding jobs. *Arcos Corp.*

273. Alloys
New Ampco Metal Catalog gives complete information on physical properties of various grades of Ampco aluminum bronze alloys. *Ampco Metal, Inc.*

274. Alloys
New catalog "Electromet Ferro-Alloys and Metals" lists over 50 metals and alloys and describes unique technical service offered to the metal industries. *Electro Metallurgical Div.*

275. Alloys, Fabricated
New catalog is available, showing cost-cutting fabricated heat treating equipment for higher pay loads and better quality. *Rolock, Inc.*

276. Ammonia
Booklet "Mathieson Anhydrous Ammonia" furnishes full information on obtaining purest ammonia from 40 conveniently located warehouses. *Mathieson Chemical Corp.*

277. Blast Cleaning
There is a Pangborn rotoblast table, barrel, or table-room designed to bring you amazing savings. Write for bulletin 214. *Pangborn Corp.*

278. Brazing
Easy-Flo — simple, versatile method of fabricating ferrous, nonferrous and dissimilar metals — is described in bulletins 12A, 15 and 17. *Handy & Harman.*

279. Cast Irons
"Production of Nodular Cast Irons with Cerium" gives details of actual practice in adding cerium to the foundry melt as developed by the British Cast Iron Research Association. First release in America. *Cerium Metals Corp.*

280. Combustion Chambers, Graphite
M-9602 describes the graphite combustion chambers and "Karbate" impervious graphite burner nozzles. Outlines operation of the complete system and points out the principal features, such as long life, absence of corrosion, minimum maintenance, ability to withstand thermal shock, simplicity and moderate installed first cost. *National Carbon Co.*

281. Conveyor Belts
Illustrated booklets, sent on request, describe conveyor belts designed for use in innumerable industrial applications. *Wickwire Spencer Steel Div.*

282. Cutting Oils
For the right combination to suit your specific requirements, write for the booklet, "Cutting Fluids for Better Machining". *D. A. Stuart Oil Co.*

283. Cutting Speed and Feed Selector
A handy, simple-to-use, circular, slide-rule type of Cutting Speed and Feed Selector is yours for the asking. This selector gives recommended feed/speed ratios for eight different stainless steels. *Republic Steel Corp.*

284. Descaling
Booklet entitled "duPont Sodium Hydride Descaling Process" discusses the process, how it works and where it is used, along with interesting photographs, diagrams and technical information, designed to help you get the most out of your scale-removal jobs. *E. I. duPont de Nemours & Co.*

285. Die Blocks
24-page booklet on "Finkl Quenched and Tempered Die Blocks" tells about four types of Finkl die block steel, how to select the right one for your job, how to make your dies last longer, and many other interesting and helpful facts. *A. Finkl & Sons Co.*

WHAT'S NEW
IN MANUFACTURERS' LITERATURE

286. Electrical Contacts
New 36-page illustrated booklet contains information on electrical contacts of value to design engineers, including fundamental notes on contact design, and thorough discussion of contact materials, properties, advantages and principal uses. *Fansteel Metallurgical Corp.*

287. Fasteners
Complete file folder contains illustrations and engineering descriptions of fasteners and fittings for resistance welding, adjusting screws, adjustable feet and other products. *Ohio Nut & Bolt Co.*

288. Films and Plates
Special sensitized plates and films for the scientific and industrial laboratories are described in a new 8-page booklet issued by the Eastman Kodak Co. *Eastman Kodak Co.*

289. Finishing
Alodine aluminum bonds paint to aluminum and protects the metal economically, with no plating equipment required. Applied with dip, spray, brush and flow coat, it provides a simple, easy process for lasting, corrosion-resistant finish. *American Chemical Paint Co.*

290. Finishing
New rotary automatic finishing machines, Super Model K-46-6, designed to handle comparatively large work such as small frames for automotive instrument panels, builders' hardware, etc. Also describes the smaller J Series for diversified grinding, polishing, buffing or deburring operations. Send for catalog No. 50. *Hammond Machinery Builders, Inc.*

291. Free-Machining Bar Steel
Reprint of article entitled "La-Led, A New Free-Machining Bar Steel", by Glenn D. Bayer, metallurgist at LaSalle Steel, discusses the advantages and characteristics of the new steel. *LaSalle Steel Co.*

292. Furnaces
Attractive new bulletin, "Cyaniding in Continuous and Batch-Type Furnaces", describes new applications in dry cyaniding. Ask for bulletin SC-145. *Surface Combustion Corp.*

293. Furnaces
For complete details on two outstanding furnaces for precise hardening and tempering of expensive tools and dies, write today for your copy of "How To Plan Your Toolroom Heat Treating Department". *Lindberg Engineering Co.*

294. Furnaces
New catalog on Heroult gantry-type electric melting furnace with patented roof-ring to assure speedy and simple bricking and elimination of skew shapes. *American Bridge Co.*

295. Gray Iron
Revised summary of Gray Iron specifications available in 4-page bulletin containing a resume of fourteen separate sets of gray iron specifications including a change in ASTM A-159-47 to ASTM A-159-49T and the addition of two new specifications covering automotive irons 113 and 114. *Gray Iron Founders' Society.*

296. Hardness Testers
Bulletin DH-114 contains full information on Tukon hardness testers for use in research and industrial testing of metallic and nonmetallic materials. Also included is bulletin DH-7, giving experiences in various fields. *Wilson Mechanical Instrument Co.*

297. Heat Treating
Pressed steel lightweight sheet alloy heat treating units furnished in any size, design or specification. Write for full information on this. *The Pressed Steel Co.*

298. Heavy-Duty Forgings
16-page booklet on "Heavy-Duty Forgings". Profusely illustrated, it shows forgings of all sizes in every phase of development from ingot to finished product. *A. Finkl & Sons Co.*

299. High-Temperature Testing
For precise hi-temperature testing send for illustrated technical folder on Marshall equipment. *L. H. Marshall Co.*

300. Immersion Heating
Bulletin IE-11 gives complete details on how new immersion pots save time and money in melting soft metals. High thermal efficiency for both large and small units provides rapid heat recovery in one-third the time. *C. M. Kemp Mfg. Co.*

301. Induction Heating
More economical production made possible through redesign of heat treating methods. Full details on application to individual plants furnished in booklet "A Tocco Plant Survey — Your Profit Possibility for 1950". *Ohio Crankshaft Co.*

302. Laboratory
New catalog "Fisher Unitized Laboratory Furniture" describes an 18-piece line of the finest, most versatile and unitized designs for complete laboratory equipment. *Fisher Scientific Co.*

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CLEVELAND 3, OHIO

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

303. Measuring Instruments
16-page booklet illustrates and describes operation of Beta Gauges in three models for measuring weight per unit area or thickness on sheet material continuously in production-line or smaller types for laboratory work. *Tracerlab, Inc.*

304. Melting, Induction
8-page illustrated article describes use of induction melting in improved technique for rotorcasting. *Ajax Engineering Corp.*

305. Mercury Cathode
Bulletin 220-I describes completely new magnetic mercury cathode Dyna-Cath and shows how it permits economical use of established procedures for high speed separation of iron in determination of aluminum in steel. *Eberbach & Son Co.*

306. Metal Cleaning
Booklet recently prepared describes new and dependable source of supply for Trichlorethylene, a new and important degreasing and metal cleaning agent. *Niagara Alkali Co.*

307. Metal Cutting
New 64-page catalog gives prices and describes complete line of rotary files, burs, metalworking saws and other products. *Martindale Electric Co.*

308. Metallizing
Bulletin 62, "Stop Corrosion with Metallizing", provides data and illustrations on various types of jobs, including spray test and life expectancy charts, for product finishing. *Metallizing Engineering Co.*

309. Metalworking Data File
Fingertip reference file 501 contains engineering information about equipment and processes used for metal stampings, heavy weldments and pressed steel shapes. *Chas. T. Brandt, Inc.*

310. Molybdenum Steels
Many important facts on lower temperatures required for heat treatment of Molybdenum high speed steel are outlined in new booklet now available. *Climax Molybdenum Co.*

311. Nickel, Gears
"Modern Trends in Nickel Steel and Cast Iron Gear Materials" contains valuable information on carburized and direct hardened nickel alloy steel gears for higher speeds and heavier loads, quieter operating and longer machine life. *International Nickel Co.*

312. Oil Burner
New 24-page catalog 410 describes the Hauck proportioning oil burner. A precision instrument for better combustion, more accurate control of furnace temperatures and atmosphere. *Hauck Mfg. Co.*

313. Oils, Cutting
A practical slide-rule-type calculator to help you maintain desired soluble oil concentrations and new bulletin containing information on Gulf Soluble Cutting Oils is available on request. *Gulf Oil Corp.*

314. Parts, Baskets
Baskets designed for your individual needs in handling parts. All types of trays, fixtures, retorts, and carburizing boxes are described in catalog 16. *Stanwood Corp.*

315. Polishing
New booklet on the Electro Polisher gives latest information on this highly improved polishing machine for the metallurgical laboratory. *Buehler, Ltd.*

316. Pressure Vessel Accessories
Valuable reference catalog 9-49 contains 60 pages of important information on pressure vessels, styles and types and other handbook material. Sent upon request on company letterhead. *Lenape Hydraulic Pressing & Forging Co.*

317. Pyro Lance
New bulletin 1724-D includes photos, complete description and prices of the Pyro Lance for temperature readings of molten metal in nonferrous foundries. *Illinois Testing Laboratories.*

318. Pyrometer
New Pyro Immersion pyrometer, especially designed for the nonferrous industry, insures uniform and sound casting. Features large direct-reading indicator for detecting temperature on minute spots, fast-moving objects and smallest streams, as illustrated in catalog 150. *Pyrometer Instrument Co.*

319. Pyrometers
For the finest results in proportional current-input control send for Bulletin PB1237, which describes the newest electronically operated pyrometer controller. *Bristol Co.*

320. Quenching
"Handbook on Quenching" contains 60 pages of helpful data on the why and how of quenching. *E. F. Houghton & Co.*

321. Quenching
For full information on the newest developments of Ajax isothermal heat treat process in martempering, austempering and other interrupted quenching operations, send for bulletin 120. *Ajax Electric Co.*

322. Refractories
New 4-page leaflet No. 312 discusses properties and applications of Taylor Sillimanite (Tasil) special refractories. *Chas. Taylor Sons Co.*

323. Salt Baths
Compact booklet containing reprint from article in Metal Progress, "Variations in the Quenching Power of Salt Baths", furnishes valuable information on procedure, calculation of cooling rates and results of this process. *American Cyanamid Co.*

324. Sawing
Bulletin 2-MP illustrates the circular sawing of metals, and new automatic triple-chip method for sawing stock up to 6" accurately without burrs. Write for details on company letterhead. *Motch & Merryweather Co.*

325. Saws
Catalog 49 describes complete line of metal-cutting saws, covering 35 models in 10 basic types, and including the world's fastest automatic production saw, the largest hydraulic hack saws, and some of the most widely used small shop saws. *Armstrong-Blum Mfg. Co.*

326. Steel, Alloy
New 24-page booklet, "How to Specify and Buy Alloy Steel with Confidence", emphasizes the importance of careful selection, positive knowledge of properties and accurate heat treatment in purchasing alloy steels. *Jos. T. Ryerson & Son, Inc.*

327. Stress-Relieving
New 4-page catalog folder describes how many unnecessary cleaning operations can be eliminated by new, practical, Steam Homo method for stress-relieving of small brass parts. *Leeds & Northrup Co.*

328. Tempilstiks°
"Basic Guide to Ferrous Metallurgy", a plastic laminated wall chart in color, furnished on request. *Tempil Corp.*

329. Testing
Bulletin 41 describes new universal testing machine for low-cost industrial production and quality control, laboratory, educational, and shop testing of metals. *Tinius Olsen Testing Machine Co.*

330. Thermocouples
Catalog 59-R tells complete story about use of Chromel-Alumel couples and extension leads. *Hoskins Mfg. Co.*

331. Thermocouples
New thermocouple catalog furnishes complete data on thermocouples, quick-coupling connectors, lead wire, protection tubes, etc. *Thermo Electric Co.*

332. Toolsteels
Countless advantages of using J & L "E" steels for better tool production described in booklet, "Faster Machining, Smoother Finish, Longer Tool Life". *Jones & Laughlin Steel Corp.*

333. Tubes, Bars, Steel
New stock list now available on 52100 tubing and bars includes specifications on forgings, chrome steel bars and chrome steel tubing. *Peterson Steels, Inc.*

334. Tubing
For full information on solving your tubing problems and details on particular uses of seamless and weldrawn types, send for bulletin 31. *Superior Tube Co.*

335. Tubing, Seamless
"Mechanical Applications" gives complete information on how seamless tubing can be economically used in your product. *Peter A. Frasse and Co.*

336. Turbines
Bulletins available as follows: Data Book 107, Gas Boosters 109, Four-Bearing 110, Blast Gates 122, Foundry 112. Descriptive Bulletin 127 and Technical Bulletin 126. Send for each by number for particular application. *Spencer Turbine Co.*

337. Vacuum Pumps
Bulletin V-45 describes complete range of high-vacuum pumps for insuring positive lubrication and long equipment life. *Kinney Mfg. Co.*

338. Welding
For full information about Airco's oxyacetylene welding supplies, including complete line of rods, fluxes and brazing rods, fluxes and brazing alloys, send for copy of Catalog 12. *Air Reduction Sales Co.*

339. Welding
Condensed data sheet giving most efficient welding procedure and selection of electrodes for best results with stainless steels. *McKay Co.*

340. Welding
Information available on fast, clean, process for welding sheet steel with the Heliarc torch. *Linde Air Products Co.*

341. Welding Equipment
Price schedule W-1 contains chart listing each of Amaco's welding products for reclamation and hardfacing: welding rods, electrodes and weldments. *American Manganese Steel Div.*

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METAL PROGRESS

7301 Euclid Avenue, Cleveland 3, Ohio

April, 1950

262	279	296	313	330
263	280	297	314	331
264	281	298	315	332
265	282	299	316	333
266	283	300	317	334
267	284	301	318	335
268	285	302	319	336
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270	287	304	321	338
271	288	305	322	339
272	289	306	323	340
273	290	307	324	341
274	291	308	325	
275	292	309	326	
276	293	310	327	
277	294	311	328	
278	295	312	329	

Please have literature circled at the left sent to me.

Name ______________________ Title ______________

Company ______________________________

Products Manufactured ______________________

Address ______________________________

City and State ______________________________

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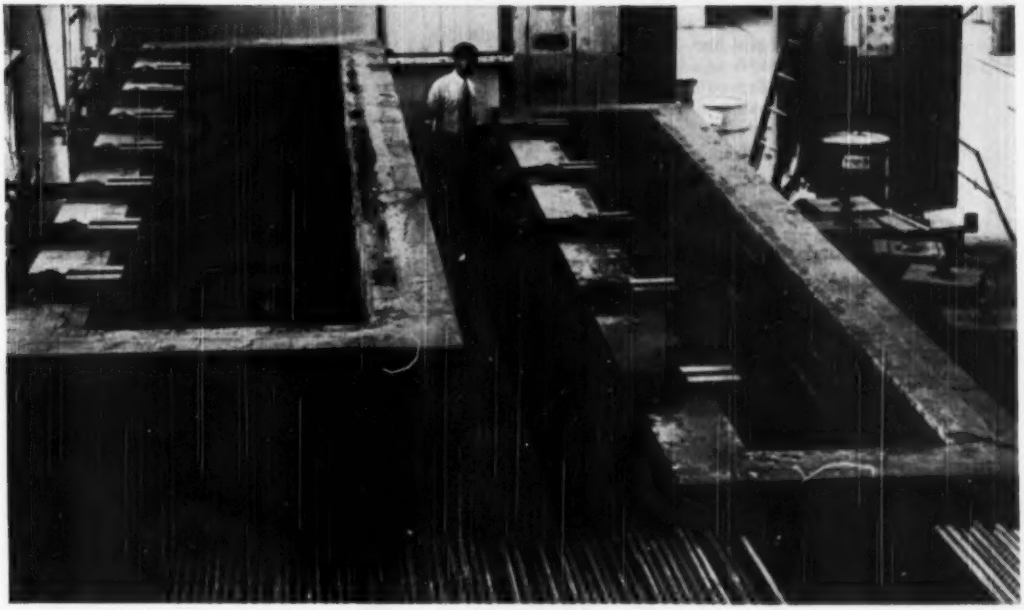
Students should write direct to manufacturers.

HOT ACID VS. "KARBATE" IMPERVIOUS GRAPHITE



WHEREVER metals are cleaned, plated or coated, "Karbate" impervious graphite equipment is an ideal material for cooling, conveying, pumping or storing the corrosive fluids involved.

"Karbate" pipe, fittings, valves, plate heaters, steam jets, pumps, tube-bundle heat exchangers, cascade coolers and related equipment are immune to attack by most commercial chemicals. This equipment is particularly well adapted to handling pickling solutions ... Parkerizing and Bonderizing baths ... nickel, copper, tin and zinc plating solutions ... and the Alumilite and Alzek processes.

"National" carbon brick are the time-tested standby in handling nitric-hydrofluoric acid solutions ... such as are used in the pickling tanks shown above. For complete information on both "Karbate" impervious graphite, and "National" carbon brick, write to NATIONAL CARBON DIVISION, Union Carbide and Carbon Corporation, Department MP.

These products sold in Canada by Canadian National Carbon Company, Ltd., Toronto 4

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German Steel

(Starts on p. 508)

in this country, although for large castings in Germany Chamotte is often preferred. Core oil compositions were modified because of shortages and many of the ersatz oils were unreliable. Core blowing was developed considerably and the efficiency of the machines used was found to be very good. An interesting development was the lining of core boxes with rubber to increase abrasion resistance where cores are blown. So-called "permanent" molds of steel or cast iron were used for some applications in static and centrifugal casting.

Cast-iron compositions used do not differ much from those used in England and America except that shortages of nickel and molybdenum forced modification of many of the alloy cast irons. Much use was made of manganese as an alloying element; about 3½% Mn was used in cast-iron rolls and up to 12% Mn with 5% Ni in austenitic cast iron. There was a considerable output of acid resisting iron containing 15% Si.

Centrifugal casting of gray iron was employed extensively for pipe, cylinder liners, piston rings and some duplex tubes with white iron bore and gray iron exterior. Both metal molds and sand lined molds were used in horizontal centrifugal casting.

Steel castings in Germany covered a wide range, from permanent magnets — a few ounces — to cupolas for the West Wall weighing over 200 metric tons. The practice for cast armor plate and for centrifugal gun tubes was remarkably similar to that used in this country. The lining of metal molds for horizontal centrifugal casting with dried quartz sand is one practice that has not been used in the United States. Steel castings were heat treated carefully to compensate for shortages in alloying elements.

Mechanization of German foundries has not been developed to the level that is economically necessary in the United States. However, there are several notable examples of highly mechanized plants. One outstanding example was a production unit at August Engels, Velbert, that was able to turn out 100 molds per hour in a floor space of 40 x 20 ft., by using hinged flasks, pendulum conveyers, overhead mono-

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German Steel

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rail for casting, and an underground belt for conveying sand from shake-out to the reconditioning unit and thence to hoppers over the machines. This unit was operated by only six men.

In general, the foundries of wartime Germany concentrated on better application of well-known principles, rather than on new developments.

C. K. DONOHO

Welding

The investigating teams agreed that the United States and Great Britain had not fallen behind Germany in cutting and joining methods during the war, but had advanced further in several respects.

Oxygen and Fuel-Gas Cutting — Torches for cutting and welding were of either the injector type or equal-pressure type. Cutting attachments were provided for both types of torch but that used with the latter required a separate hose for the cutting oxygen which made the torch more cumbersome and awkward to handle. Cutting nozzles were of the internal-external type utilizing a ring flame preheat.

Deseaming torches for use on ingots, slabs and billets had cutting orifices ranging in diameter from 6 to 9 mm. (¼ to ⅓ in. approx.). With these torches the deseaming speeds ranged from 5 to 16½ ft. per min. and oxygen consumption from 850 to 1550 cu.ft. per hr.

An underwater cutting torch utilized benzene as fuel, which was fed to the torch through a hose at 135 psi. pressure. The oxygen for preheating and cutting was supplied at 200 psi. and before reaching the regulator was warmed by passing through a hot water bath. The nozzle consisted of an internal and an external member, both screwed onto the torch head independently. The external member was longer in order to provide a chamber from which water could be excluded and in which the preheating and cutting could take place. All gas passages were in the internal member.

Flame cutting machines in Germany were of a type quite common in the United States wherein a carriage, operating longitudinally on rails of any desired length, carries a cross slide which overhangs the

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German Steel

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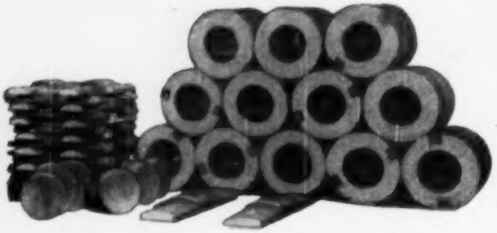
carriage on either or both sides. The overhanging end or ends of this slide carry the cutting head or heads so that either one or two plates may be cut at one time. Guiding of the cutting heads was accomplished by one of three methods: *(a)* magnetic roller on a steel template, *(b)* twin rollers on a metal strip template, or *(c)* tracing device working directly from a drawing. The template or drawing was fixed on the table between the rails for guiding the cutting head. Templates were made of material about 10 mm. thick (0.4 in.). The largest type of cutting machine used in production utilized a track gage of 3.5 m. (about 11.5 ft.).

Welding Electrodes — Resistance-welding electrodes of 99% Cu, 1% Cd, manufactured by Dürener were used by a majority of welding machine manufacturers although many firms used electrodes of pure copper. It was apparent that German manufacturers had not been aware of the importance of proper maintenance of resistance-welding electrodes.

With reference to arc-welding electrodes it was found that the production standard in Germany was not so high as that of Great Britain and production was not so highly mechanized. Some electrodes were dipped but most were extruded. Quality control was not an outstanding feature of manufacture. Krupp was more thorough in testing electrodes; operating tests included observation of spatter, weld and slag appearance, weld metal porosity, ease of slag removal and ease of welding in the vertical position. These were supplemented by tests of several types of rigid joints to determine weld metal cracking susceptibility.

The first recorded production welding of armor in Germany was in 1923 when electrodes used were strips cut from armor plate and used uncoated with direct current. A patent to Böhler in 1933 deals with austenitic welding of non-austenitic steels. It is pointed out that in 1927 welding of armor with austenitic electrodes was being practiced by the Research Department of Woolwich Arsenal. The development work begun by Krupp in 1933 resulted in two electrodes, a 25% Cr, 20% Ni (NCT3) and an 18% Cr, 8% Ni, 2% Mo. By 1941 electrode development was in progress in the

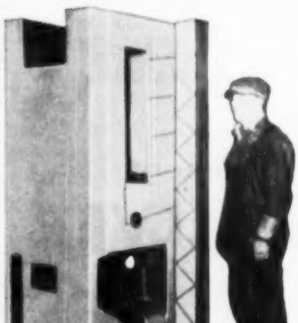
(Continued on p. 534)



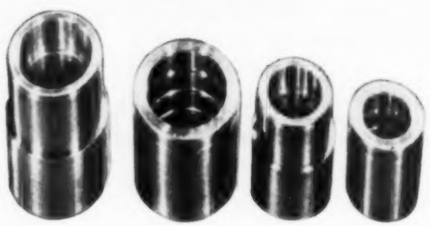
Rolling Mill . . . Screw-down Nuts — Ampco alloys are selected for their high resistance to terrific pressures and impact. Rolling mill pressures are transferred through the screw to the nut threads. In cases such as a blooming mill, this pressure is applied with impact — increasing from zero to several million pounds in a fraction of a second. That's why they need the tough strength of centrifugally cast Ampco aluminum bronze.

Earth-moving Equipment . . . Excavator Roller Bushings — Ampco Grade 16 selected for unusual wear resistance, excellent bearing qualities and high load-bearing strength. Turntable roller bushings must carry the tremendous weight of the cab, boom, and load. The turning is slow but eccentric because of the cantilever action of the boom and load. Ampco bronze alloys also used for gears, plates, cams, sleeves, and many other important excavator parts.

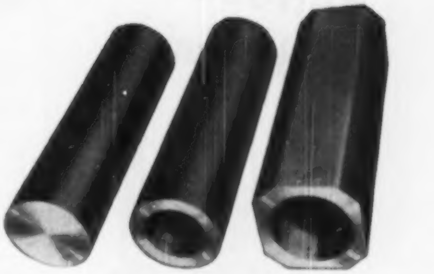
Garden Tractors . . . Worm Gears — Ampcoloy E-123 aluminum bronze selected for high strength and wear resistance, high impact and fatigue values. Reduced replacements to a mere 1/10 of the previous average. This outstanding saving is typical, accounts for the specification of Ampco aluminum bronzes for a wide variety of gears — from tiny fishing-reel gears to giant 1-ton gears for rolling mills.



Forging Machinery Upsetter Slides — Ampco Grades 18 and 20 selected by one manufacturer to replace hardened steel because they combine excellent bearing qualities with the necessary strength to withstand a 40,000 psi load. In two and a half years of service they showed little signs of wear. The same high physical properties make these alloys ideally suited for such applications as wear strips and wear plates.



Die Sets . . . Guide Pin Bushings — Ampco Grade 18 selected for its hardness and excellent bearing qualities. Seizing and galling are eliminated. Exceptional resistance to wear maintains tolerances. Correct alignment is assured regardless of speed of travel. Tests by one concern show Ampco guide pin bushings give 2½ times the life of previous material. Standard bushings are centrifugally-cast from Grade 18 Ampco Metal.



German Steel

(Starts on p. 508)

laboratories of three other firms, Böhler, Agil (Austria) and D.E.W.

German experience with welded armor during the first winter of the Russian campaign led to an appreciation of the importance of good notch-impact performance of weld metal at subzero temperatures. Tests were conducted at temperatures from 68 to −94° F. with the specimen notch in weld metal. Commercially available ferritic-type electrodes gave weld metal values at −94° F. of the order of 20% of the room temperature value. The austenitic weld metals, however, gave values of the order of 50% of the room temperature value. The austenitic weld metals were of two types — 18% Mn, 12% Cr and 18% Cr, 8% Ni, 6% Mn. A standard composition of 19% Mn, 12% Cr was adopted for welding armor plate thicker than about ⅝ in.

The German Navy would not completely accept this standard electrode composition. For welding armor, only the Krupp NCT3/133 was permitted. This is believed to be a modified 25-20 electrode. The unsatisfactory experience of German industry with the standard manganese-chromium electrode as regards weld metal cracking led to the approval of a manganese-modified 18-8 electrode in three brands — Böhler Fox A-7, Krupp V-10-A and D.E.W. Thermanit X.

This switch to high-alloy electrodes by German industry resulted in increased alloy consumption which alarmed the German Steel Alloy Control. Early in 1943 an energetic search for a suitable lower-alloy electrode for welding armor was instituted. A low-alloy electrode (R.N.D.) giving a weld metal of low yield point and high ductility was developed by Agil Chemie (Berlin). This electrode contained a total of 1% to 1¼% Mn with low carbon and had a basic lime-fluorspar coating. The resulting weld metal contained 0.60 to 0.75% Mn, 0.25 to 0.35% Si, with 0.08% C. The yield point was of the order of 46,000 to 50,000 psi. with a tensile strength of 55,000 to 60,000 psi. and elongation of 33 to 40% and 60 to 80% reduction of area. Similar electrodes were developed by Krupp (EV 420) and Böhler (P.N.A.) and all three were used in large-scale fabrication.

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German Steel

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For comparison, the ferritic electrode development in the United States, NRC-2A electrode, gave a weld metal of about 85,000 psi. yield with tensile strength of 95,000 psi. Its composition was manganese-molybdenum with low carbon. The most promising British electrode with hydrogen-controlled coating for welding armor was the Ferex, a mild steel electrode.

The coatings of the most successful German ferritic electrodes developed for welding armor had a very limited potential hydrogen content and were similar to those usually used for austenitic electrodes. The coating binder was sodium silicate. The success in welding armor with this type of electrode was attributed to the use of very low welding currents. For the 5-mm. diameter electrode (about $\frac{7}{32}$ in.) a maximum amperage of 160 was prescribed. With these low currents, operating characteristics of electrodes were poor. In order to minimize occurrence of root bead cracking it was directed that the root deposit be made with an austenitic electrode and the joint completed with an accredited ferritic electrode (R.N.D.).

Welding Technique and Applications — Heavy aluminum sections were mostly welded with the oxy-hydrogen gas process. Arc welding had very limited use for this purpose but when it was used preheating was employed. Welds in corrosion resisting material were annealed when corrosion resistance was particularly important. Both the electric-arc and atomic-hydrogen welding processes were used for steel castings. Preheating was not used unless the castings were large and important. For preheating, the temperature of the casting was raised to 570°F. and a weld bead deposited. This bead was then peened and ground smooth before the next bead was deposited. This procedure was followed until the weld was completed.

Defects on the outside surface of armor castings where the depth of defect was not over 15% of the wall thickness were permitted to be repaired by welding. The atomic-hydrogen process was preferred for this work because it was claimed that good results could be obtained with unskilled personnel.

For miscellaneous applications in

(Continued on p. 538)

German Steel

(Starts on p. 508)

large-quantity production butt welding in fully automatic resistance-welding machines was used in preference to flash welding. Both flash-butt welding and thermit welding were extensively used for welding rail joints on other than first-class railway lines. Welding was extensively used in building highway and railway bridges of the plate girder type. The results have been quite satisfactory.

In ship construction welding was used for butt joints in the hull, decks and tank tops of cargo ships. Covered electrodes up to 7 mm. (5/16 in.) diameter were used but none of these were of the so-called "hot rod" type (E-6010) which do not appear to have been developed in Germany. Machine welding was not used to any extent although some experimenting was carried on with the Unionmelt and Ellira processes. All wire and powder flux required were made in Germany. In some submarine hulls the longitudinal and circumferential joints were welded with Unionmelt from the outside only. The inside welds were made by hand. Machine welding data recorded were: Material thickness, 5/8 to 3/4 in.; 800 to 1200 amperes, 38 to 42 volts.

Research and Testing—Extensive welding research was carried on at the Krupp Research Institute and Experimental Station. All aspects of welding appear to have been covered but development of armor-welding electrodes occupied a prominent position. Due to alloy shortages in 1943 the armor-welding program reverted from use of austenitic electrodes to the EV 420 (pure iron) electrode. Attempts to develop low-alloy electrodes which would give a martensitic weld metal of mechanical properties similar to the armor proved unsatisfactory due to brittleness of the weld metal. Studies of failures in weld metals of high tensile strength indicate that the Germans were well aware of the relationship between "fish eyes" in the weld metal and hydrogen from the electrode coating. It was generally regarded by the Krupp investigators that austenitic electrodes should be designed for direct current, as the use of alternating current promotes weld metal cracking. Other sources indicate that for alternating-current welding a substandard frequency with an open-

(Continued on p. 542)

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Courtesy Rittling Corp.

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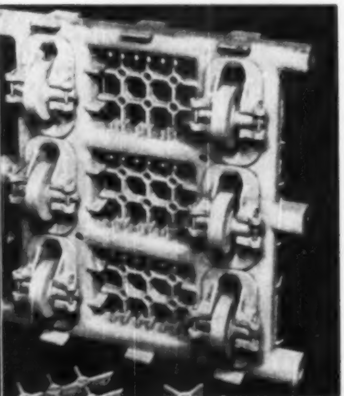


A backward glance, as WE MOVE FORWARD

Much gas has gone through carburetors since G. A. began growing up with the automotive industry! We've learned that progress means *change*.

Thirty years separate the Engineering and Production thought,—the owner satisfaction,—typified by these "sports" and "family" cars. Dreams and sweat, trial and error, bitter disappointment and stimulating success fill that gap.

The depression buried the American "two-seater", the "speedsters" and "sportsters" already dying from lack of cost-comparable performance. Europeans more idealistic and individualistic than "practical",—as we used to be,—produce fast, roadable high performance "sports" and "super sports" cars for eccentrics who like to take-the-road unsurrounded by 130-odd cubic feet of luxurious solarium, with three feet of fore and aft overhang. They enjoy a feeling of unity with spirited mounts whether equine, aerial or aquatic. There are others who believe that "that which is truly functional is truly beautiful" and do not like their personal possessions festooned with phony vents, deceptively massive "guards", and chrome-plated "garbage", but they offer a small market. Idyllic cars do not pay off like high breeding in race horses or top technology in alloys.

The old cars shown are: (1) Mercer "Raceabout",—which sold for $4200 and had no near competitor in roadability, and (2) McFarlane,—"Sport Coupe", —with floating fenders, and a 150 H. P., 6 cylinder, "T" head, 18 spark plug fire-engine motor. Al Grinnell, late G. A. Detroit Manager, is shown in the Mercer. H. H. H. drove it 100,000 miles. Al drove it another 100,000 plus. It is still running in Detroit.

The Cadillac's companion is British, Jaguar, Super-Sports Model, which holds the World's speed record of 132.6 miles per hour for "production" cars ("production car" means over 25 have been built). A twin-overhead camshaft, 6 cylinder engine of 210" displacement, develops 160 H. P. at 5000 R.P.M. and peaks at 5700, has low compression ratio of 7 to 1 and no mechanical complexities. Weight, 2360 pounds. 16 miles per gallon. It has torsion rod front springing, a wind tunnel stream-lining job, compact top enclosure ample luggage space, all of the usual accessories with superb attention to detail, including an adjustable steering wheel on a telescoping column, and jacks which operate from inside the body and lift two wheels simultaneously. Just a clean, well engineered job by W. M. Heynes, Chief Engineer of Jaguar Cars Limited, Coventry. Acceleration is: 0 to 30—2.5 seconds; 0 to 50—5.3 seconds; 0 to 60—9.2 seconds; 0 to 80—16.7 seconds; 0 to 100—33.1 seconds. A break-in period is required to condition driver's reaction. We bought the Jaguar as our 50th birthday present to retard our hardening arteries.

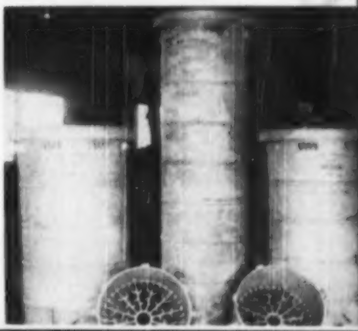
Performance is FACTUAL in automobiles or alloys. It is definite, irreparable proof of the integrity, engineering and manufacturing skill in the product. If you keep records of your alloy performance, if you buy alloy on the basis of "cost-per-heat-hour", you know what we mean. You will agree that you cannot afford "cheap alloys". Some folks will say: "What can you do with such speed and acceleration?" Their fathers and grandfathers probably asked the same question.

If American automobile producers ever decide to produce two-seaters,—for guys who feel lonesome, rattling around in a six-place job, like a peanut in a drum,—we may give the British a run for this small market. Meanwhile, add the name of Heynes to those whose ideology, ability and perseverance have attained surpassing achievement. His Product PERFORMS!

An "editorial" by the President of General Alloys Company, Boston—"oldest and largest exclusive manufacturer of heat and corrosion resistant castings".

OLD. *Alloy carburizing boxes, crude and heavy by modern standards, cut iron and steel box weights 50 to 80%.*

NEW. *G. A. 3/8" cast muffles and fixtures equip principal gas carburizing installations.*



THE FOOTSTEPS OF GENERAL ALLOYS MARK THE PATH OF AN INDUSTRY

German Steel

(Starts on p. 508)

circuit voltage as low as 65 is beneficial.

The importance of X-ray examination of welds for testing welders and for inspection control of weld quality was generally recognized. Various forms of weld bend tests were used for qualification of procedures and testing the weldability of base metals. For development testing of welded pressure vessels Krupp utilized a method whereby fluctuating internal pressures could be applied up to a frequency of 50 cycles per min. and producing stresses in the shell almost up to the yield point of the metal. Most of the testing was performed at 8 to 15 cycles per min. because the higher frequencies were considered to produce more of an impact loading.

At Karlsruhe, Dr. Dörnen conducted fatigue tests of full-size plate girder bridges using a hydraulic ram as a loading device. Several million cycles were imposed before a fracture developed and Dr. Dörnen believes that for fabricating plate girder bridges by welding, the higher welding currents and heat inputs give better results.

Repairing — Elaborate and detailed instructions for repairing armor structures by welding were issued by the German Army High Command. These repairs included clean penetration up to about 4 in. diameter, large damaged areas and cracks in armor plate. Originally two electrodes were approved for this work — "Union B Elite Seelenelektrode" and "SH 52 lila" — but by a revision of the directive three other electrode brands (18-8 with 6% Mn) were permitted: "D.E.W. Thermanit X", "Böhler Fox A-7", and "Krupp V-10-A". The electrode "Union B Elite Seelenelektrode" gives weld metal properties between bare or lightly-coated electrodes and covered electrodes. It was made by drilling a steel billet prior to rolling and drawing into wire. This hole was filled with a flux or electrode coating material and the billet was then reduced to wire form. Thus, the electrode is a bare wire containing the coating material as a central core. The revision of the directive suggests that the use of the two electrodes originally approved did not produce results which were wholly satisfactory, at least in the repair of defects in armor.

W. L. Warner

German Steel

(Starts on p. 508)

Coatings

Metallic Coatings — The chief methods employed for metallic coatings included hot dipping, electrodeposition and cladding.

The procedures used for the manufacture of tin-plate and tinned strip were continuous hot dip tinning of strip steel, electrolytic tinning of sheets and continuous electrolytic tinning of strip.

The procedure for tinning cast iron was: *(a)* pickle in 10 to 20% hydrochloric acid, *(b)* dry in sawdust without washing or neutralizing, *(c)* shot blast with fine crushed grit, *(d)* dip in "killed" spirits of salts, *(e)* dip into molten commercially pure tin at 535 to 570° F., *(f)* remove and re-dip in "killed" spirits, *(g)* dip again into molten tin, *(h)* repeat *f* and *g* (up to five times) to obtain a good continuous coating, *(i)* dip in water to cool, and *(j)* dip in oil for protective coat.

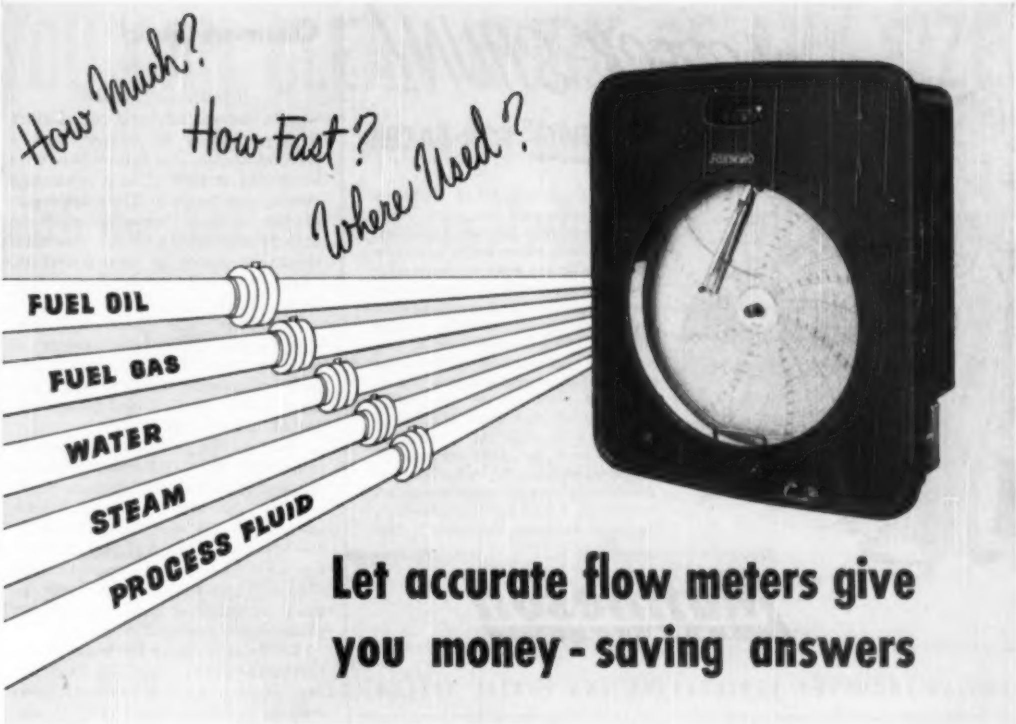
For hot galvanizing of wire, one sequence consisted of: *(a)* anodic degreasing, *(b)* water wash, *(c)* hydrochloric acid, *(d)* water wash, *(e)* anodic sulphuric acid, *(f)* water wash, *(g)* zinc ammonium chloride flux, and *(h)* coating in a galvanizing kettle.

The Langbein-Pfanhauser electrogalvanizing plant for steel wire operated with the following sequence: *(a)* despooling, *(b)* electrolytic degreasing at 194° F. in a solution of sodium hydroxide and sodium carbonate, *(c)* acid bath followed by water wash, *(d)* alkaline bath — cold solution of sodium carbonate, *(e)* electrolytic cleaning bath — chemically pure sulphuric acid, *(f)* water wash combined with mechanical cleaning by passage through sharp sand, *(g)* plating bath with an electrolyte of patent composition consisting essentially of zinc sulphate solution maintained at 32° Bé (bath temperature 104 to 108° F., pH value 4.8), *(h)* water rinse, *(i)* drying by passing through a hot air chamber, and *(j)* winding.

It was said that from the viewpoint of corrosion resistance, wires hot dipped were more satisfactory than those electrogalvanized. This was attributed to the iron-zinc alloy layer, which is not formed in electrogalvanizing.

The procedure in brass plating

(Continued on p. 546)



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MONEY-SAVING FLOW METERS

German Steel

(Starts on p. 508)

was to deposit on hard rolled steel, first, a coating of copper, then a coating of zinc and follow this with annealing at 1100° F. in a controlled atmosphere furnace. The thicknesses of the deposits were arranged to give a 70-30 Cu-Zn alloy. The total thickness aimed at was 0.0003 in. Both zinc and copper baths consisted of acid electrolytes.

A patent was discovered concerning the electrolytic coating of iron and steel with chromium. The point of interest was that this treatment had to be followed by annealing at 1920 to 2100° F.

One of the problems in connection with the production of chromium coatings by diffusion methods was to develop a method which gave an evenly distributed layer on the surface of the material forming the base. The Krupp experimental station found that halogen salts applied in either a liquid or gaseous phase were especially suitable.

Bi-Metal — At the Harkort-Eicken Edelstahlwerke G.m.b.H. (parent firm Hoesch A.G., Dortmund), iron containing more than 0.1% C and 0.4% Mn was used for the core metal of clad strip. The following steels were used as covering metals:

C	Mn	Cr	Applications
0.6	1.0	—	Agricultural implements
1.2	0.5	0.35	Safes
1.5	0.3	1.50	Duplex files

Data obtained from D.E.W., Krefeld, includes a review of the existing patents on the cladding of iron or steel with molybdenum for protection from attack by molten zinc. In view of the cost of the process, D.E.W. initiated research on a method for the electrolytic deposition of pure molybdenum on iron.

Mild steel strip has also been coated with aluminum and with copper, and used as electric cable tape, stove fittings, telephone diaphragms and flexible metallic tubing. Copper-clad steel strip was made for small-arms bullet jackets and cartridge cases, the usual cladding being 10% Cu, 90% steel. Copper sheet was laid on sand-blasted steel sheet bars, heated to about 1740° F. and rolled hot. Reference is made to two treatises by Dr. Hougardy (D.E.W.) which list metals suitable for cladding and give information on rolling practice and on the application of clad materials in the chemical industry. *(To p. 548)*

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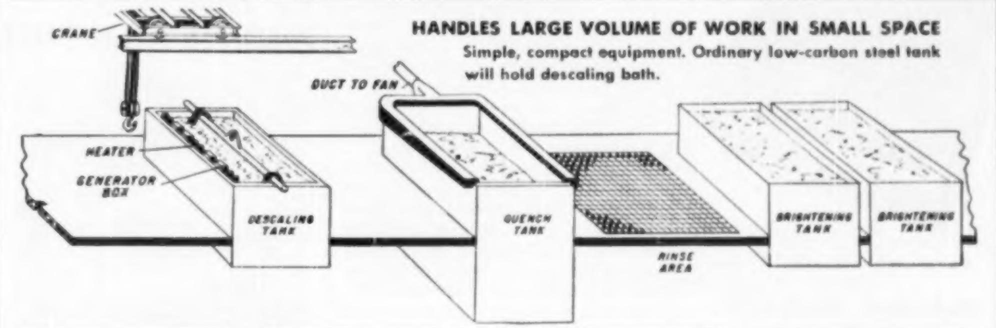

BATH
Sodium hydride reduces the scale quickly without pitting or loss of base metal. Action stops as soon as scale is reduced.

QUENCH
Steam generated by the hot work blasts off most of the loosened scale.

RINSE
High-pressure water rinse leaves work ready for inspection, galvanizing, machining, etc. Also removes smut remaining after brightening.

BRIGHT DIP
(Optional)
Diluted acid gives bright surfaces when required. After rinsing, work is finished or ready for further processing.

REMOVE SCALE quickly and completely from a wide variety of metals, alloys, and bimetallics—in any size or shape—with this modern descaling method.

HANDLE DIFFERENT METALS in the same operation . . . alloy steels, stainless steels, nickel, cobalt, copper, chrome . . . any work not affected by the carrier bath of fused caustic at 700° F. Installations now in operation are descaling all types of finished articles and processed stock, ranging from small parts weighing only a fraction of an ounce to huge stainless sheets over 3 tons in weight.

FOR COMPLETE INFORMATION on a process that can mean important savings in metal, time, space, equipment, materials, and the disposal of waste products—mail the coupon below. It will bring you promptly a copy of "Du Pont Sodium Hydride Descaling Process," which describes the process and tells how easily it can be installed and used.

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German Steel

(Starts on p. 508)

For the manufacture of thermostatic bi-metal, the component commonly used for the low side was a nickel-iron alloy (36 to 42% Ni), but the component for the high side was selected from a much wider range which included nickel, 70-30 brass, Ni-Fe (25% Ni), Ni-Mn-Fe (14 to 20% Ni, 5 to 6% Mn), and Ni-Mo-Fe (27% Ni, 5% Mo). The stages in manufacture include: *(a)* preparing the contact surfaces of the two materials by grinding or machining, *(b)* making a compact by wrapping in thin iron sheets or by the use of rivets, *(c)* heating in a suitable atmosphere, and *(d)* rolling with a heavy initial pass.

The types of steel used for production of compound sheets were also used for bi-metal tubing, with the lining or sheathing, or both, consisting of stainless steel. Steel tubing lined or sheathed with copper or bronze has also been produced in Germany. Copper-covered steel tubing was produced largely of a composite containing approximately 20% of the cladding metal.

The method for inside cladding consisted of cleaning by sand blasting the inner surface of the steel tube and the outer surface of the copper, drawing these cold, one upon the other, and bonding by heating this assembly to approximately 1800° F. Bonding resulted from the greater expansion on heating of the inside copper tube.

These types of cladding operations were not carried out with brass or other copper alloys containing considerable quantities of zinc. A high-copper bronze (96% Cu, 2% Zn, 2% Sn) was reported to have been used in considerable quantities as the inner lining of bi-metal tube for brake cylinders.

Cold and hot rolling experiments were tried on steel clad with nickel, copper and brass. Under cold rolling conditions, it was found that one-side cladding increased deformation resistance, while two-side cladding reduced it. Bullet jackets made of steel plated with Tombak (90 Cu, 10 Zn) were produced.

Nonmetallic Coatings — Manufacturers of metal containers devoted much effort to the development and perfection of lacquering techniques, and practically all works with a tinning plant also operated a lacquering plant. At Dinslaken the oven for the continuous lacquering of

(Continued on p. 550)

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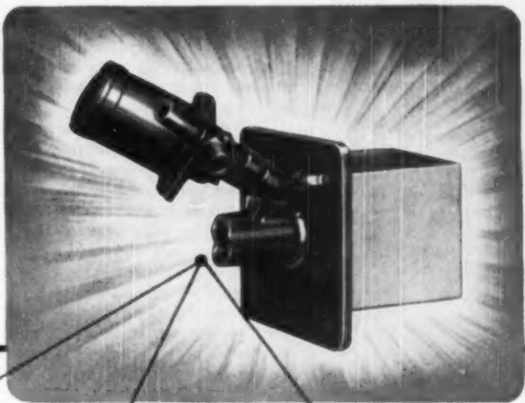

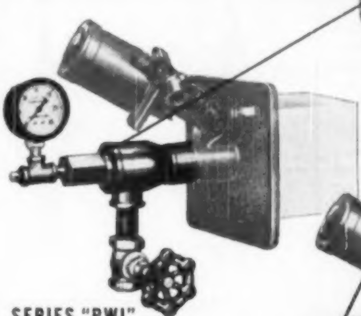

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McKee Piloted Walltite Proportioning Burners—a combination of the Series "PW" Burner and the McKee Low Pressure Proportional Mixer so that each burner is a complete gas-air mixing and burning unit. The use of a Zero Governor with the Burner provides one valve control by air regulation only. In 12 sizes, capacities 11,000 to 900,000 BTU per burner. For details write for Bulletin H-62.

This new addition to the McKee Eclipse Family of Walltite Burners will be welcomed by users of sealed burners requiring instantaneous flame failure protection and constant pilot.

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Eclipse Fuel Engineering Company McKee Eclipse
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German Steel

(Starts on p. 508)

strip for packaging was originally 100 m. long. In most cases, their procedure was to apply 10 g. of high-bake phenolic lacquer per sq.m. of strip surface designed for the inside of the can (two 5-g. coatings) and 5 g. per sq.m. for the outside. Both sides of the strip were baked at once, the strip being edge-carried on coned disk rollers.

Pitch or bitumen coatings for spun pipe usually consisted of 65% pitch and 35% heavy anthracene oil. This mixture had to be carefully maintained at 250° F. during the time the pipe was in the dip, normally ½ to 1 min. After dipping, pipes were immediately racked and allowed to drain and cool.

Interesting reports have been prepared on the bonding of rubber to steel and other metals, also on veneer-faced steel. It was reported that the only method which had been employed on a large production scale was the brass-bonding process, and that only one new bonding material had been discovered — a compound known as "Desmodur R". Stainless steel and cast iron are difficult to brass-plate, and "Desmodur R" could be used on these alloys with advantage.

Phosphate processes for the surface treatment of iron and steel had long been used by the Germans. There were innumerable users of these processes on a large or small scale, all employing one or another of a limited number of proprietary processes emanating from specialist firms who supplied the treatment, chemicals, specific instructions for use and technical information.

The hot phosphating processes remain predominant, but the recently introduced cold processes have made rapid strides. Accelerators were used with all the latter methods, but approximately half of the hot processes were unaccelerated. The practice with the unaccelerated process is said to have the sequence:

Pre-treatment (removal of scale and grease)

Phosphating

After-treatment (rinsing, drying and applying sealing coating after a black stain treatment).

It has been common practice to use a water-oil emulsion of 10 to 25% shell oil No. 54 of Rhenania-Ossag, Hamburg, for sealing.

ADOLPH BREGMAN

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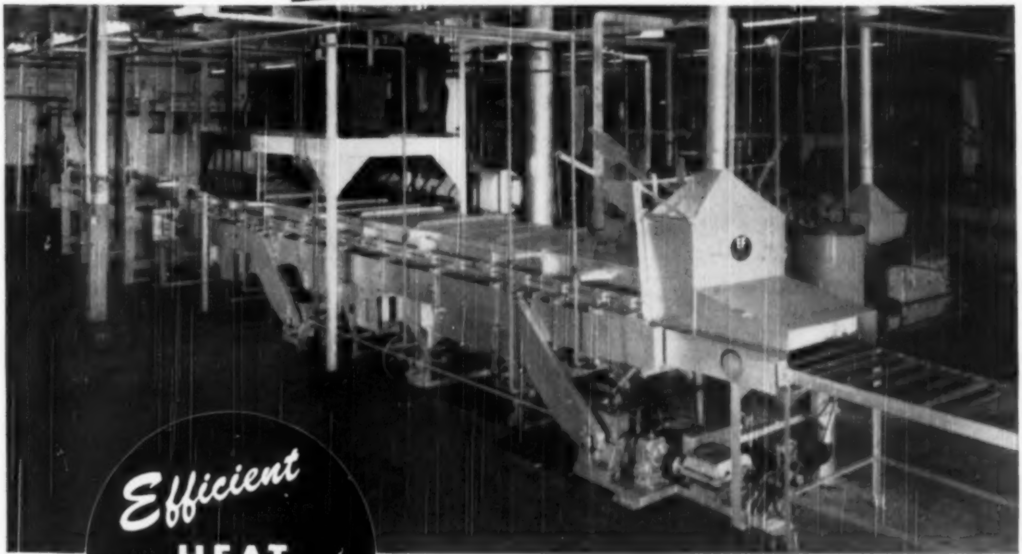

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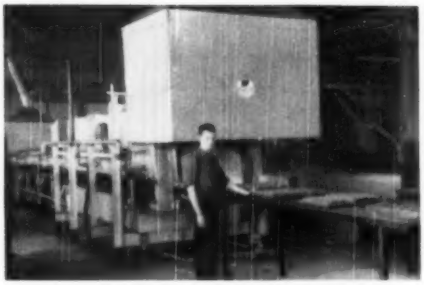

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